ERDC/CERL TR-00-29

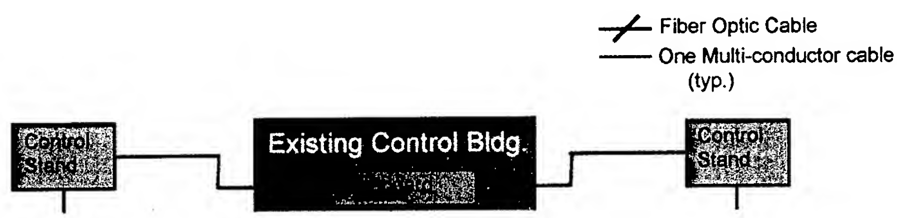
Construction Engineering Research Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

Critical Evaluation of Lock Automation and Control Equipment at Corps-Operated Navigation Locks

by Patrick Wilson, L.D. Stephenson, and Ashok Kumar

September 2000



Approved for public release; distribution is unlimited.

ERDC/CERL TR-00-29

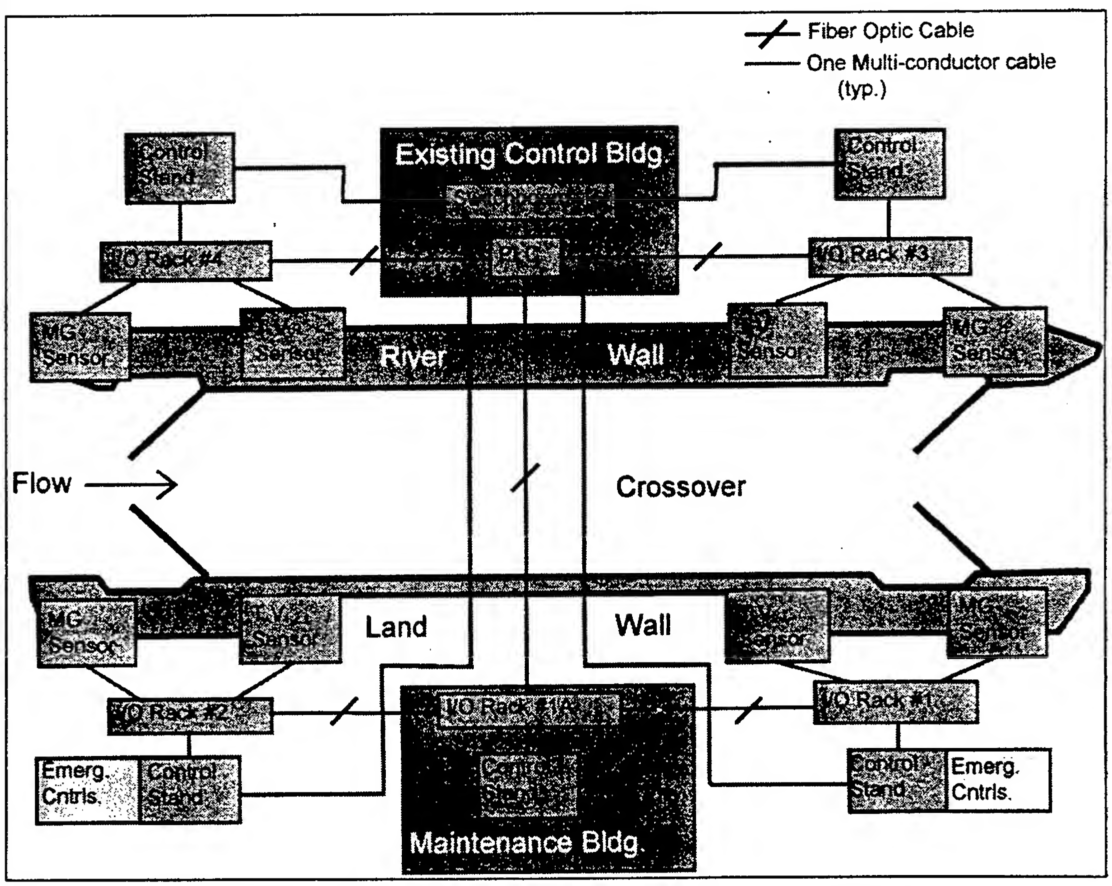
Construction Engineering Research Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

Critical Evaluation of Lock Automation and Control Equipment at Corps-Operated Navigation Locks

by Patrick Wilson, L.D. Stephenson, and Ashok Kumar

September 2000



Programmable logic controller (PLC) system with a partial hardwired backup system.

Approved for public release; distribution is unlimited.

Innovations for Navigation Projects
Research Program

ERDC/CERL TR-00-29
September 2000

Critical Evaluation of Lock Automation and Control Equipment at Navigation Locks Operated by the U.S. Army Corps of Engineers

by Patrick Wilson, L.D. Stephenson, and Ashok Kumar

Construction Engineering Research Laboratory
U.S. Army Engineer Research and Development Center
PO Box 9005
Champaign, IL 61826-9005

Final Report

Approved for public release; distribution is unlimited

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under INP Work Unit 33125

Foreword

This report was prepared for Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Innovations for Navigation Projects (INP) Research Program. The study was conducted under Work Unit 33125, "Innovations for Lock Gate Operating Controls and Equipment," managed at the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS.

Dr. Tony C. Liu was the INP Coordinator at the Directorate of Research and Development, HQUSACE. Dr. Reed L. Mosher, ERDC Structures Laboratory (SL), was the Laboratory Manager for the INP Program; Dr. Stan Woodson, ERDC SL, was the INP Program Manager.

The work was performed at the ERDC Construction Engineering Research Laboratory (CERL) by members of the Materials and Structures Branch (CF-M), Facilities Division. The Principal Investigator was Dr. Ashok Kumar. The report was prepared by Mr. Patrick Wilson, Dr. L.D. Stephenson, and Dr. Kumar. Mr. Mark W. Slaughter is Acting Chief, CEERD-CF-M, and Mr. L. Michael Golish is Chief, CEERD-CF. The Acting Technical Director of the Facility Acquisition and Revitalization business area is Dr. Paul A. Howdyshell, and the Acting Director of CERL is Mr. William D. Goran.

At the time of publication of this report, Dr. James R. Houston was Director of ERDC, and COL James S. Weller, EN, was Commander.

Contents

List of Figures and Tables

Figures

Tables

1 Introduction

Background

Shrinking operations and maintenance (O&M) resources, personnel reductions, and increased river traffic are putting increased demands on the U.S. Army Corps of Engineers (USACE) ability to operate and maintain its locks. Lock automation technology can help to meet those demands. The Corps has automated lock operations at a number of projects, and there are additional opportunities where the Corps can take advantage of this type of technology.

The Corps operates and maintains 238 navigation locks at 192 sites on U.S. waterways (see Figure 1). Of this total, only 19 locks at 15 sites have automated their lock operations using programmable logic controllers (PLCs). As river traffic continues to increase while Corps O&M resources remain constant or decrease, lock automation technology offers the potential to improve operational safety, efficiency, and reliability.

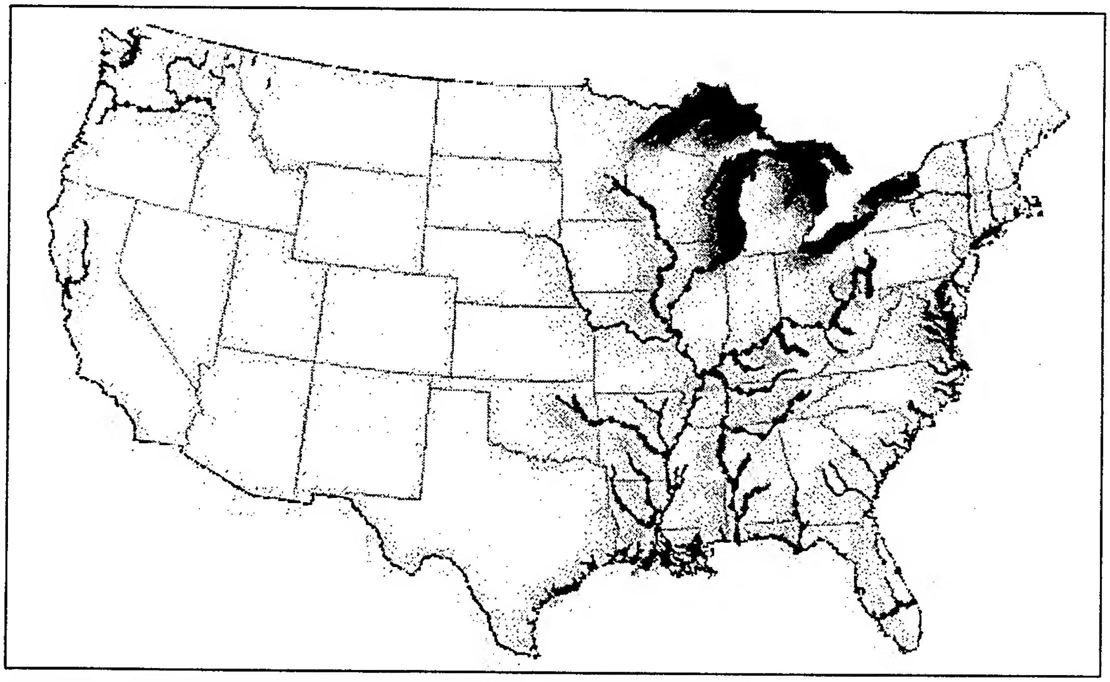


Figure 1. Locations of Corps-operated locks in the United States.

The Corps began experimenting with PLC-based lock automation in the 1980s. Each PLC application was custom-designed for a specific lock site, based on the experiences and preferences of the engineers and other key personnel at that site (e.g., electricians and lockmasters). The level of automation that was implemented also was determined through consideration of factors such as local river traffic, lock physical dimensions, gate types, lift requirements, etc.

It is reasonable to expect that standardized specification and design of lock automation technologies by the Corps of Engineers could lead to wider adoption and improve the safety, efficiency, and reliability of lock operations. A logical starting point toward this end is to evaluate lock automation systems already in place at Corps-operated lock sites in order to help to identify both successful and unsuccessful applications, in addition to 'learning curve' issues that may be reduced through standardized specifications.

The automation of 15 lock sites by eight Army Engineer Districts has been documented in several technical publications (for example see Bannister, Kwong, and Nelson 1996; Emmerling 1996; Porter 1996). In these cases, engineers have networked various sensors (lock gate position indicators, water level sensors, filling and emptying valve position indicators, etc.) to PLCs. These automated systems offer various benefits, such as providing lock personnel more accurate operating information in the control room and creating electronic interlock safety systems that eliminate the possibility of human error during certain key lockage tasks. For example, a safety interlock can be programmed into the PLC to prevent lock gates from being opened until water levels are equal on both sides of the gate. Another example: magnetic or inductive proximity switches and position encoders can be networked to a PLC to provide greater accuracy and reliability than lever arm switches in positioning gates and valves.

In 1995 personnel at U.S. Army Engineer District Rock Island (i.e., Rock Island District) conducted a study of four lock control system alternatives and considered the economic impact of each one for Mississippi River Lock and Dam No. 14 at Pleasant Valley, Iowa (Radtke and Rodgers 1995). The four alternatives studied were:

1. hardwired relay-based system
2. single PLC control system
3. PLC control system with a backup central processing unit (CPU)
4. PLC control system with a partial hardwired backup control.

These alternatives were analyzed with respect to several factors, including but not limited to the following:

1. initial costs
2. maintenance costs
3. life cycle costs
4. technical advantages and disadvantages.

It was found that alternatives 2, 3, and 4 (i.e., PLC-based systems) provided considerable costs savings over a standard hardwired system that uses only relays. However, although the Rock Island District recognized the benefits offered by PLC-based control systems, a relay-based hardwired control system ultimately was recommended for use at Lock and Dam No. 14 because of the concerns and experiences of the District. The Rock Island District does have one lock that uses a PLC control system with a backup CPU — Lockport, located at Lockport, IL, on the Illinois Waterway. The control systems at this lock are among those discussed in this report. The Rock Island District Study is presented in Appendix A.

Objectives

The objectives of this study were to:

- systematically evaluate the current status of PLC-based lock control system at Corps-operated facilities, based on procurement specifications and field experience
- document the field data, findings, and related analysis for use by Army Engineer Districts that are considering upgrades of existing locks or new construction.

Approach

CERL identified 19 lock chambers at 15 lock sites where PLCs are used to control machinery that operates lock gates and valves in conjunction with pool level indicators, gate and valve position sensors, etc. A survey of these sites was then conducted with assistance from the eight Army Engineer Districts in which the locks with PLC-based control systems were located (listed below). The survey included onsite inspections plus interviews with lockmasters, lock operators, maintenance personnel, and engineers. Below is a list of the participating Districts and lock sites:

- **St. Louis District**
  Lock and Dam 24
  Lock and Dam 25
  Melvin Price Locks and Dam (main and auxiliary locks)
  Locks No. 27 (main and auxiliary)

- **Nashville District**
  Barkley Lock and Dam
  Wilson Locks and Dam (main and auxiliary locks)
  Wheeler Locks and Dam (auxiliary locks)
  Pickwick Locks and Dam (auxiliary lock)

- **Jacksonville District**
  Port St. Lucie Lock

- **New Orleans District**
  Leland-Bowman Lock
  Calcasieu Lock

- **Portland District**
  Bonneville Lock and Dam

- **St. Paul District**
  Lock No.1 (two 400-ft lock chambers)

- **Huntington District**
  Winfield Lock and Dam

- **Rock Island District**
  Lockport Lock and Dam

To standardize evaluative criteria CERL developed an evaluation matrix for application to the lock operating components, which were divided into the following categories: PLC system, operator interface (OI), sensors and switches, and closed-circuit television (CCTV) systems. Where possible these components were evaluated according to two sets of criteria:

- the features available as listed on the manufacturer's specification sheets
- performance reports by lockmasters, maintenance personnel, and lock operators.

The information gathered during this study is presented in two different forms. Chapter 2 presents a narrative overview of each lock facility, including an outline of both objective data from specification sheets and subjective comments obtained through field interviews. Key objective data are summarized in tables that immediately follow the introductory comments about each facility. (Note that some components at a few lock sites were obsolete; some table entries may be blank if the required specification was unavailable.) Opinions and anecdotal information from field personnel are then summarized in lists (organized by category) that immediately follow the tables. The data from the specification and performance evaluation forms used in the field are presented in Appendix B. The specification evaluation forms indicate how various lock components compare with equivalent state-of-the-art components. The performance evaluation forms indicate how well the equipment has performed in a specific application at a particular lock site, based on the experiences of lock and District personnel. CERL and District personnel developed weighting factors for each criterion in the evaluation matrix. The weighting factors are intended to reflect the relative importance of each evaluation factor. For example, device reliability or the availability of spare parts may be more critical than other rating factors.

After evaluating the Corps-operated locks controlled by PLCs and visiting other locks in Europe and Panama, draft specifications for lock automation equipment were prepared. Appendix C contains proposed lock control specifications in the form of draft Corps of Engineer Guide Specifications (CEGS) for control systems, instrumentation systems, computers, and networks used in lock automation systems. These draft specifications, prepared for this study by St. Louis District, are designated as follows:

- CEGS SECTION 16900: CONTROL AND INSTRUMENTATION (Draft)
- CEGS SECTION 16910: PROGRAMMABLE LOGIC CONTROLLER (Draft)
- CEGS SECTION 16920: INDUSTRIAL PERSONAL COMPUTERS AND NETWORKS (Draft).

Mode of Technology Transfer

It is recommended that the results of this study be incorporated into existing Corps of Engineers guidance (e.g., Engineer Manual [EM] 1110-2-2610, Chapter 4) and a future Corps guide specification for incorporating automation into lock operating control systems.

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

SI conversion factors		
1 ft	=	0.305 m

2 Results and Discussion: Lock Evaluations

St. Louis District (CEMVS) Locks

There are about 28,000 square miles of land in eastern Missouri and Southwestern Illinois that make up the St. Louis District. Some of the water resource related tasks undertaken by the district include flood damage regulation navigation, and hydropower.

Four locks in the St. Louis District are included in this study: Lock and Dam No. 24, Lock and Dam No. 25, Melvin Price Locks and Dam, and Locks No. 27. Melvin Price has the most automated lock control system of those visited. Locks 24 and 25 were recently upgraded to PLC-control under the same contract. Locks No. 27 has a PLC system similar to that of Melvin Price without as much automation of its procedures. All of these locks are particularly busy and key to the shipping of cargo, with Locks No. 27 being the busiest lock on the Mississippi.

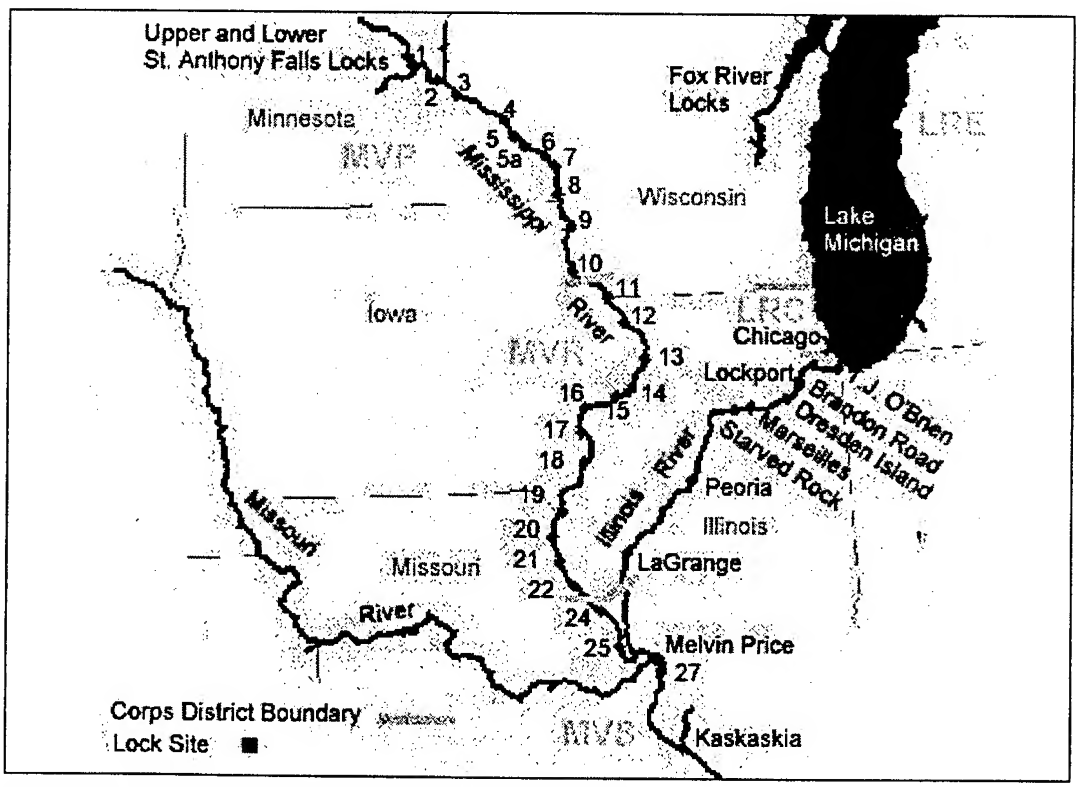


Figure 2. Locations of St. Louis District Locks visited.

Lock, Dam, and Pool No. 24

Clarksville, MO, 26 May 1999
Lockmaster — Chris Morgan, 573-242-3524
Electrician — Bob O'Shea, 573-242-3524
Project Engineer — Andy Schimpf, 314-331-8269

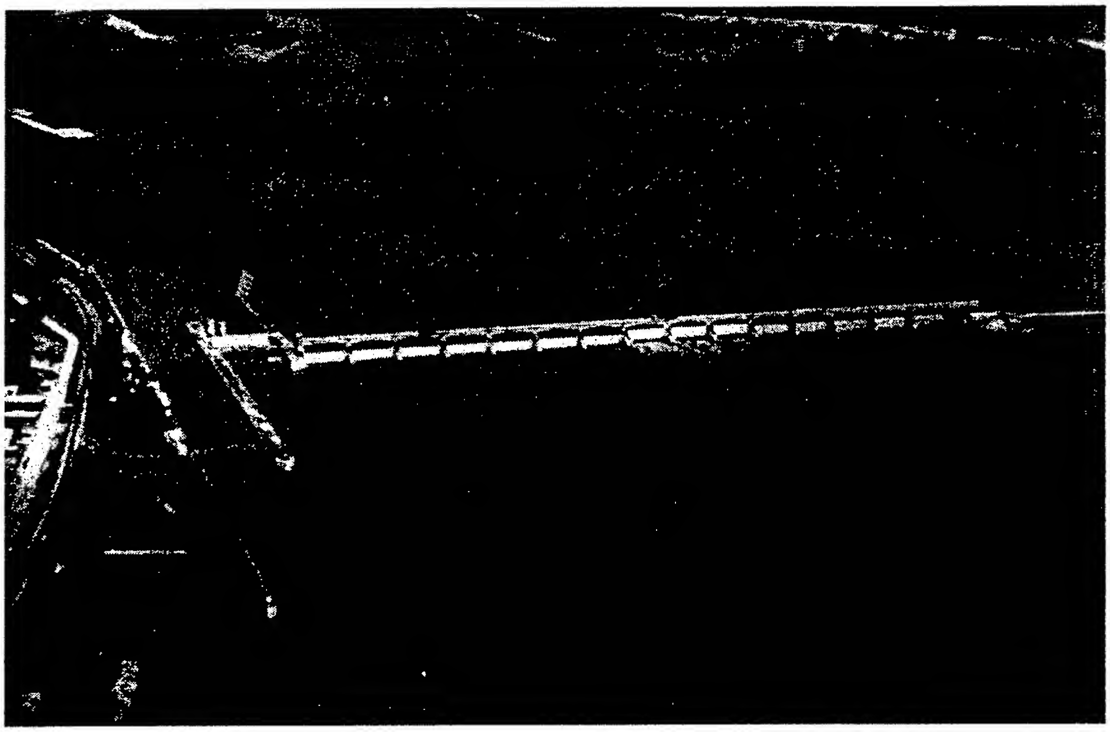


Figure 3. Aerial view of Lock, Dam, and Pool No. 24.

Facility Overview

Lock and Dam No. 24 is located near Clarksville, Missouri at mile 273.4 on the Mississippi River. It is a unit of the overall plan to provide a nine-foot navigation channel from the mouth of the Missouri River to Minneapolis, Minnesota. The lock chamber is 110 ft wide X 600 ft long. The height of the lock chamber from its floor to the top of the lock wall is about 30 ft. The lock usually experiences about a 10 ft lift. The lock has miter gates at both the upstream and downstream ends and uses tainter valves for filling and emptying the chamber. The gates and valves of the lock are operated by electric motors. In 1998, traffic at the lock consisted of 3521 lockages for a total of just over 34.7 million tons of cargo.

There are lock control stations located at both upstream and downstream ends of the lock on the land wall side. Only the gates, valves and other components in the immediate vicinity of a control station can be operated from that control sta-

tion (i.e., only upstream gates can be operated from the upstream control station).

The lock normally operates in manual mode via the PLC system. This means that the lock operator has to initiate each stage of the lockage (i.e., equalize pool level, open gates, close gates, etc.). Lock control in all of the control stations is conducted using Allen Bradley RS View 32 OI software running on an industrial personal computer (IPC). A graphical user interface (GUI) depicting the layout of the lock is displayed on the monitor of the IPC. The lock operator uses a mouse to point and click on the icons corresponding to the desired lock operations (open gates, fill chamber, blow horn, etc.). The safety interlocks for lock operations are integrated into the programming of the PLC. In the event of PLC failure, there are hardwired backup systems in place to run all lock machinery. However, this means operation without the benefit of the safety interlocks.

This lock was opened for use in 1940. It has been operating with PLC-based controls since its last major rehab during the winter of 1998-1999.

Evaluation Findings

Table 1 describes the PLC.

Table 1. General PLC description of Lock, Dam, and Pool No. 24.

Subject	Comments
Input	Limit switches, position indicators, pressure transducer
Output	Gate motor drivers, valve motor drivers, bubbler system driver
Manufacturer	Allen Bradley
Processor	Allen Bradley-5/80C
Network Design	Windows NT Client/Server
System Design	No comment provided
PLC Programming Software	Allen Bradley RSLogix5

Additional comments about the PLC:

- Safety interlocks can be revised and improved so much more easily since they are contained within software
- The programming software is user friendly and able to accommodate all kinds of updates and changes
- The PLC system is really great. Safety interlocking changes and trouble-shooting is a keystroke away.
- The network operates over ControlNet Ethernet. The amount of traffic on the lines is not large enough for this to cause any signal delay problems

- Having the PLC has alleviated the risk of electrocution operators faced at the local control stations. Before the PLC system was in place, the relay-based control stations were directly connected to 240 V for running the gate motors.
- RSLogix allows convenient organization of control rungs making it much easier to access and alter control program
- RSLogix5 has conventional left-to-right ladder logic as well as convenient function block programming
- The bubbler system to remove debris can now be operated from the control room instead of having to walk outside and do it.

Table 2 describes the operator interface.

Table 2. General OI description of Lock, Dam, and Pool No. 24.

Subject	Comments
Type	PC/GUI
Manufacturer	Industrial Computer Source 7415K6-23V-B3
PC Components	Various Industry Leaders
Monitor	NEC LA-2031JMW-1
Design	No comments provided
OI Software	RSView 32

Additional comments about the operator interface:

- Drag and Drop feature when used with RSLogix is very handy for integrated programming
- The anti-glare coating on the display is not effective during the high glare periods of the day
- The user interface is easy to learn and has become indispensable to the operators
- Database complete and easy to access from programming screens
- Test features are convenient
- Good selection of dynamics for animating graphics on operating screens
- Speed is good when used with ethernet.

Table 3 describes the water level indicator.

Table 3. General water level indicator comments on Lock, Dam, and Pool No. 24.

Subject	Comments
Type	Pressure transducer
Manufacturer	Druck PTX 1880
Body Material	Titanium
Electronics	No comments provided
Reliability	There has been no trouble to this point
Accuracy	0.06% FS

Additional comments about the water level indicator:

- The pressure transducer for pool level indication is one of the best advantages of the added electronics
- The titanium bodies appear to have some resistance to zebra mussel infiltration
- Replacement is very simple and quick
- Units require periodic cleaning of filter screens.

Table 4 describes the gate position indicator.

Table 4. General gate position indicator comments on Lock, Dam, and Pool No. 24.

Subject	Comments
Type	Rotating shaft position indicator
Manufacturer	Astrosystems, Inc. DuraPot HDC40 PT
Body Material	No comments provided
Electronics	Direct wire 4-20 mA output
Reliability	The devices are very good
Accuracy	0.05% FS

Additional comments about the miter gate position indicator:

- Encoder is absolute type and requires no resetting or recalibrating following a power failure, even if gate was moved while the power to the transducer unit was down
- Encoder puts out a direct 4-20 mA signal compatible with any PLC analog input card
- Inherent surge and lightning protection help keep the PLC system operating.

Table 5 describes the overtravel and high-tension indicator.

Table 5. General gate overtravel and high-tension indicator comments on Lock, Dam, and Pool No. 24.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Cutler Hammer
Body Material	NEMA 6P
Electronics	Dry Contact SP 1NO/1NC
Reliability	They have been very reliable
Accuracy	They are very accurate

Additional comments about the gate overtravel and high-tension indicator:

- The lever-arm limit switch is housed with the sector gears near the electric motor running the miter gate
- The high-tension limit switches are mounted on the miter gate leaves where the sector arm attaches to each leaf

- Overtravel limit switches are hardwired to the miter gate starter buckets to prevent damage when operating in the emergency hardwired mode.

Table 6 describes the change-of-gate-speed indicator.

Table 6. General change-of-gate-speed indicator comments on Lock, Dam, and Pool No. 24.

Subject	Comments
Type	Rotating shaft position indicator
Manufacturer	Astrosystems, Inc. DuraPot HDC40 PT
Body Material	No comments provided
Electronics	Direct Wire 4-20 mA
Reliability	The devices are very good; they have built-in surge and lightning protection
Accuracy	0.05% FS

Additional comment about the change of gate speed indicator:

> The gate speed position encoder described also gives indication to the PLC for speed changes.

Table 7 describes the valve position indicator.

Table 7. General valve position indicator comments on Lock, Dam, and Pool No. 24.

Subject	Comments
Type	Traveling nut limit switches
Manufacturer	Cutler Hammer
Body Material	No comments
Electronics	No comments
Reliability	They have been very reliable since 1939
Accuracy	They are very accurate

Additional comment about the valve position indicator:

> In major rehab during 1998 – 99 these limit switches were cleaned, retensioned, contacts resoldered, and placed back in service as inputs to the PLC control system. This was done because the units have been so reliable for 60 years.

Table 8 describes the valve overtravel indicator.

Table 8. General valve overtravel indicator comments on Lock, Dam, and Pool No. 24.

Subject	Comments
Type	Traveling nut limit switch
Manufacturer	Cutler Hammer
Body Material	No comments
Electronics	No comments
Reliability	It's been very reliable since 1939
Accuracy	It's been very accurate

Additional comment about valve overtravel indicator.

> During major rehab 98-99, these limit switches were cleaned, retensioned, contacts resoldered, and placed back in service as inputs to the PLC control system. This was done because the units have been so reliable for 60 years.

Table 9 describes the mitered/open indicator.

Table 9. General mitered/open indicator comments on Lock, Dam, and Pool No. 24.

Subject	Comments
Type	Magnetic switch
Manufacturer	General Electric Model #CR115A58AF and CR115X2 (magnet)
Body Material	No comments
Electronics	No comments
Reliability	They've been very reliable
Accuracy	.007-inch accuracy (repeatablity)

Additional comments about mitered/opened indicator:

- Switches have no external moving parts to wear out
- They have been in satisfactory use at other projects for 10+ years.

Table 10 describes the dam-gate position indicator.

Table 10. General dam-gate position indicator comments (tainter gate).

Subject	Comments
Type	Force Balance Inclinometer
Manufacturer	Columbia Research Labs, Inc. Model SI-701BI
Body Material	Stainless Steel NEMA 13
Electronics	Totally encapsulated direct 4-20 ma output
Reliability	It's been very reliable
Accuracy	.2% FS

Additional comments about the tainter gate position indicator:

- The inclinometer is used for gate height indication and shutting down the motor of the tainter gate on the dam in case of no movement of the gate
- The inclinometers allow remote (on-site) operation of the dam. This gives the lock operators more time to concentrate on operation of the lock.

Table 11 describes the dam-gate overtravel indicator.

Table 11. General dam-gate overtravel indicator comments on Lock, Dam, and Pool No. 24.

Subject	Comments
Type	Traveling nut limit switch
Manufacturer	Cutler Hammer
Body Material	No comments
Electronics	No comments
Reliability	It's been very reliable
Accuracy	It's very accurate

Additional comment about tainter gate overtravel indicator:

> During major rehab 98-99, these limit switches were cleaned, retensioned, contacts resoldered, and placed back in service as inputs to the PLC control system. This was done because the units have been so reliable for 60 years.

Table 12 describes the CCTV system.

Table 12. General CCTV system comments on Lock, Dam, and Pool No. 24.

Subject	Comments
Purpose	Monitor chamber and gate activity for recording and help in debris detection
Camera	Panasonic WV-BP310 B&W CCD Camera (obsolete model with no specifications data available)
Camera Housing	Pelco: In 1996 the camera housing was upgraded to the then current pressurized model. That model is now obsolete and no specifications data is available.
Monitor	Sony SSM-171 17" B&W monitor (obsolete model with no specification data available)
Design	The high mast lighting was an excellent decision. It really makes a difference at night.

Lock, Dam, and Pool No. 25

Winfield, MO, 26 May 1999
Lockmaster — Jerry L. Stroud (636) 566-8120
Electrician — Mike Quinn (636) 566-8120
Project Engineer — Andy Schimpf (314) 331-8269

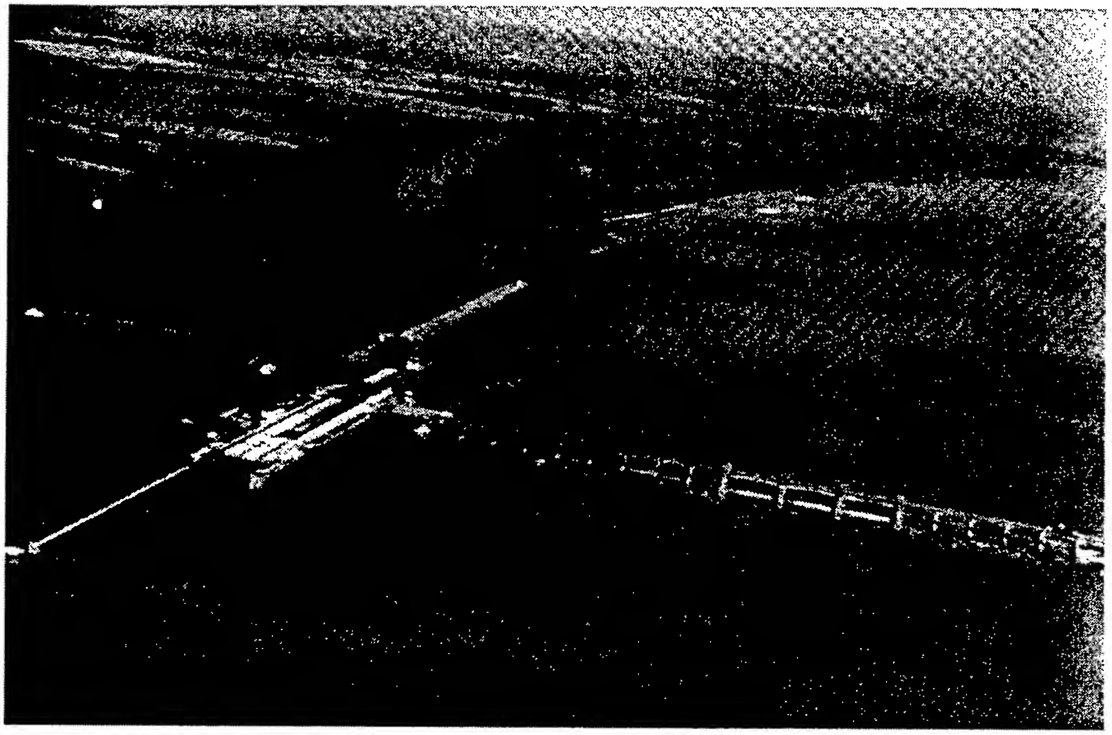


Figure 4. Aerial view of Lock, Dam, and Pool No. 25.

Lock and Dam No. 25 is located near Winfield, Missouri at mile 241.4 on the Mississippi River. It is a unit of the overall plan to provide a nine-foot navigation channel from the mouth of the Missouri River to Minneapolis, Minnesota. The lock chamber is 110 ft wide X 600 ft long. The height of the lock chamber from its floor to the top of the lock wall is about 39 ft. The lock can handle a maximum lift of 15 ft. The lock has miter gates at both the upstream and downstream ends and uses tainter valves for filling and emptying the chamber. The gates and valves of the lock are operated by electric motors. In 1998, traffic at the lock consisted of 3840 lockages for a total of just over 34.8 million tons of cargo.

There are lock control stations located at both upstream and downstream ends of the lock on the land wall side. Only the gates, valves, and other components in the immediate vicinity of a control station can be operated from that control station (i.e., only upstream gates can be operated from the upstream control station). The lock normally operates in manual mode via the PLC system.

Lock control in all of the control stations is conducted using the Allen Bradley RS View 32 OI software running on an IPC. A GUI depicting the layout of the lock is displayed on the monitor of the IPC. The lock operator uses a mouse to point and click on the icons corresponding to the desired lock operations. The safety interlocks for lock operations are integrated into the programming of the PLC. In the event of PLC failure, there are hardwired backup systems in place to run

all lock machinery. However, this means operation without the benefit of the safety interlocks.

This lock was opened for use in 1939. It has been operating with PLC-based controls since its last major rehab during the winter of 1998 – 1999.

Table 13 describes the PLC.

Table 13. General PLC comments on Lock, Dam, and Pool No. 25.

Subject	Comments
Input	Limit switches, pressure transducer, temperature probes, position transmitter
Output	Valve drivers, gate drivers, air bubbler system driver
Manufacturer	Allen Bradley
Processor	Allen Bradley-5/80C
Network Design	Windows NT Client/Server
System Design	No comments provided
PLC Programming Software	RSLogix5 PLC Programming Software

Additional comments about the PLC:

- Safety interlocks can be revised and improved so much more easily since they are contained within software
- The bubbler system to remove debris can now be operated from the control room instead of having to walk out and do it
- Having the PLC has alleviated the risk of electrocution lock operators faced at the local control stations. Before the PLC system was in place, the relay-based control stations were directly connected to 240 V for running the gate motors
- RSLogix allows convenient organization of control rungs making it much easier to access and alter control programs
- The network operates over ControlNet ethernet. The amount of traffic on the lines isn't large enough for this to cause any signal delay problems
- The PLC system is really great. Safety interlocking changes and troubleshooting are a keystroke away
- The programming software is user friendly and able to accommodate all kinds of updates and changes
- RSLogix5 has conventional left-to-right ladder logic as well as convenient function block programming.

Table 14 describes the OI.

Table 14. General OI comments on Lock, Dam, and Pool No. 25.

Subject	Comments
Type	PC/GUI
Manufacturer	Industrial Computer Source 7415K6-23V-B3
PC Components	Various Industry Leaders
Monitor	NEC LA-2031JMW-1
Design	No comments provided
OI Software	RSView 32 OI software

Additional comments about the OI:

- The anti-glare coating on the display is not effective during the high glare periods of the day. The user interface is easy to learn and has become indispensable to the lock operators
- Drag and Drop feature when used with RSLogix is very handy for integrated programming
- The database is complete and easy to access from programming screens
- Test features are convenient
- Good selection of dynamics for animating graphics on operating screens
- Speed is good when used with ethernet.

Table 15 describes the water level indicator.

Table 15. General water level indicator comments on Lock, Dam, and Pool No. 25.

Subject	Comments
Type	Pressure Transducer
Manufacturer	Druck PTX 1880
Body Material	Titanium
Electronics	No comments provided
Reliability	There has been no trouble to this point
Accuracy	0.06%

Additional comments about the water level indicator:

- The pressure transducer for pool level indication is one of the best advantages of the added electronics
- The titanium bodies appear to have some resistance to zebra mussel infiltration
- Replacement is very simple and quick
- Units require periodic cleaning of filter screen.

Table 16 describes the gate position indicator.

Table 16. General gate position indicator comments on Lock, Dam, and Pool No. 25.

Subject	Comments
Type	Rotating shaft position transmitter, absolute resolver type
Manufacturer	Astrosystems, Inc. DuraPot HDC40 PT
Body Material	Direct 4-wire 4-20 ma output
Electronics	No comments provided
Reliability	The devices are very reliable
Accuracy	0.05% FS

Additional comments about the gate position indicator:

- Encoder is absolute type and requires no resetting or re-calibrating following a power failure, even if the gate was moved while the power to the transducer unit was down
- Encoder puts out a direct 4-20mA signal compatible with any PLC analog input card
- Inherent surge and lightning protection help keep PLC system operating.

Table 17 describes the gate overtravel and high-tension indicator.

Table 17. General gate overtravel and high-tension indicator comments on Lock, Dam, and Pool No. 25.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Cutler Hammer
Body Material	NEMA 6P
Electronics	Dry Contact SP 1NO/1NC
Reliability	They are reliable
Accuracy	Once calibrated, they are accurate

Additional comments about the overtravel and high-tension indicator:

- The lever-arm limit switch is housed with the sector gears near the electric motor running the miter gate
- The high-tension limit switches are mounted on the miter gate leaves where the sector arm attaches to each leaf
- Overtravel limit switches are hardwired to miter gate starter buckets to prevent damage to machinery when operating in the emergency hardwired mode.

Table 18 describes the valve position indicator.

Table 18. General valve position indicator comments on Lock, Dam, and Pool No. 25.

Subject	Comments
Type	Traveling nut
Manufacturer	Cutler-Hammer
Body Material	No comments
Electronics	No comments
Reliability	Has been very reliable since 1939
Accuracy	It is very accurate

Additional comment about the valve position indicator:

> During major rehab 98-99, these limit switches were cleaned, retensioned, contacts resoldered, and placed back in service as inputs to the PLC control system. This was done because the units have been so reliable for 60 years.

Table 19 describes the valve overtravel indicator.

Table 19. General valve overtravel indicator comments on Lock, Dam, and Pool No. 25.

Subject	Comments
Type	Traveling nut
Manufacturer	Cutler Hammer
Body Material	No comments
Electronics	No comments
Reliability	Very reliable since 1939
Accuracy	Very accurate

Additional comment about the valve overtravel indicator:

> During major rehab 98-99, these limit switches were cleaned, retensioned, contacts resoldered, and placed back in service as inputs to the PLC control system. This was done because the units have been so reliable for 60 years.

Table 20 describes the mitered/open indicator.

Table 20. General mitered/open indicator comments on Lock, Dam, and Pool No. 25.

Subject	Comments
Type	Magnetic switches
Manufacturer	General Electric Model #CR115A58AF and CR1158X2 (magnet)
Body Material	Stainless Steel NEMA 13
Electronics	No comments
Reliability	There has been no trouble to this point
Accuracy	0.007 inch accuracy (repeatability)

Additional comments about the mitered/opened indicator.

- Switches have no external moving parts to wear out
- Have been in satisfactory use at other projects for 10+ years.

Table 21 describes the dam-gate position indicator (tainter gates).

Table 21. General dam-gate position indicator comments (tainter gates) on Lock, Dam, and Pool No. 25.

Subject	Comments
Type	Force Balance Inclinometer
Manufacturer	Columbia Research Labs, Inc Model SI-701BI
Body Material	No comments
Electronics	Totally encapsulated direct 4-20 ma output
Reliability	It has been reliable so far
Accuracy	0.2 % FS

Additional comments about tainter gate position indicator:

- The inclinometer is used for true gate height indication and shutting down the motor of the tainter gate on the dam in case of no movement of the gate. This prevents slacking of the chains in the event a log, ice, or other obstruction inhibits the movement of the gate
- The inclinometers allow remote (on-site) operation of the dam giving the operators more time to concentrate on operation of the lock.

Table 22 describes the dam-gate position indicator (roller gates).

Table 22. General dam-gate position indicator comments (roller gates) on Lock, Dam, and Pool No. 25.

Subject	Comments
Type	Rotating shaft position transmitter, absolute resolver type
Manufacturer	Astrosystems, Inc. DuraPot HDC40 PT
Body Material	No comments provided
Electronics	Direct wire 4-20 ma output
Reliability	The devices are very good
Accuracy	0.05% FS

Additional comments about the roller gate position indicator:

- Encoder is absolute type and requires no resetting or re-calibrating following a power failure, even if the gate was moved while the power to the transducer unit was down
- Encoder puts out a direct 4-20mA signal compatible with any PLC input card
- Inherent surge and lightning protection help keep PLC system operating.

Melvin Price Locks and Dam

Alton, IL, 25 May 1999
Lockmaster — Tom Miller (314) 899-1543
Engineer Staff POC — Mike Sommars (314) 331-8279
Electrician — Bill Jones (314) 899-1543

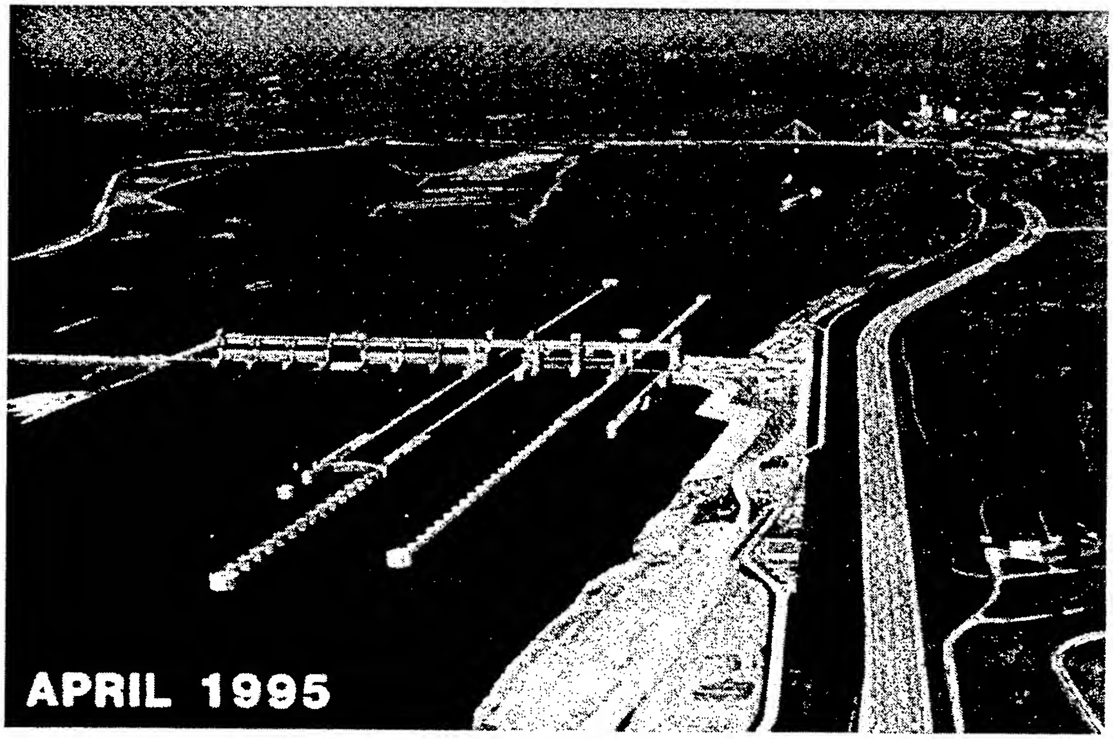


Figure 5. Aerial view of Melvin Price Locks and Dam.

The Melvin Price Locks and Dam, which replaced Locks and Dam No. 26, is located at Mississippi River mile 200.8 near Alton, Illinois. It is approximately 2 miles downstream from the old Lock and Dam No. 26 project. The structure contains two lock chambers. The main lock is 110 ft wide X 1200 ft long. The auxiliary lock is 110 ft wide X 600 ft long. The main lock has a pair of miter gates on the downstream end and a series of three 13 ft high vertical lift gates on the upstream. Two leaves are the operating leaves and raise and lower with each lockage. The third is essentially a movable sill that automatically adjusts with changing pool conditions. In 1998, the total traffic of the main and auxiliary locks consisted of 7672 lockages for a total of just over 73.6 million tons of cargo.

There are a total of 10 locations at the lock from which an operator can control lock operations. The central control room is located in the tower midway between the auxiliary and main locks. The PLC system can only be operated from the central control station. There are two local control stations at each end of

the main and auxiliary locks. These control stations operate using a hardwired control system. Full indication of lock equipment status is available in all of the control stations. There is also an intermediate control station that is located in the pier adjacent to the main lock on the Missouri side. Each of the local control stations is capable of operating both the upstream and downstream culvert valves and the lock gates on their respective end of the lock.

Melvin Price Locks and Dam is the only COE site that uses semi-automatic control. Both the auxiliary and main locks can be operated in semi-automatic mode from the central control room only. Semi-automatic control implies that the lock operator initiates the preparation of the downstream or upstream end of the lock with a single command (i.e., pool level is equalized, the bubbler system clears debris, and the gates are opened or closed automatically following a single command).

All of the gate and valve motors and pumps as well as the CCTV, air bubbler, and lighting systems are controlled by the PLC system.

The OI software for lock control in the central control room is Square D Streamline 2.0 running on an IPC. A GUI depicting the layout of the lock is displayed on the monitor of the IPC. The lock operator uses a mouse to point and click on the icons corresponding to the desired lock operations. The safety interlocks for lock operations are integrated into the programming of the PLC. The lock can be controlled from a remote location through the computerized control system via the Internet or dial-up networking using the built-in security access features.

The lock has been operating with Square D PLC controls since the main lock went into operation in 1989. A Square D 500 processor for the PLC system came with the original installation. In 1992, the lock upgraded to the Square D 655 processor with ethernet communications.

Table 23 describes the PLC.

Table 23. General PLC comments on Melvin Price Locks and Dam.

Subject	Comments
Input	Limit switches, pressure transmitters, position transmitters
Output	Gate-motor drivers, valve-motor drivers, air bubbler drivers
Manufacturer	Square D
Processor	Square D SY/MAX 655
Network Design	Windows NT Client/Server
System Design	No comments
PLC Programming Software	Square D Class 8030 Type SFW374/375 Universal Programming Software

Additional comments about the PLC:

- All lock operations are programmed into the PLC
- Ladder logic as provided by contractor has been replaced with program written by engineers at St. Louis District
- There is a separate processor and ladder logic program for each lock
- The dam is currently controlled through the main lock processor, but could be controlled from the auxiliary lock processor by adding the necessary ladder logic
- Remote troubleshooting is performed with both locks.

Table 24 describes the OI.

Table 24. General OI comments on Melvin Price Locks and Dam.

Subject	Comments
Type	PC/GUI
Manufacturer	Industrial Computer Source (90 Mhz and 166 Mhz Intel Pentiums)
PC Components	Various industry leaders
Monitor	19 inch rackmount CRT IPC Video Display monitor
Design	No comments
OI Software	Square D Streamline version 2.0

Additional comments about the OI:

- The OI is pretty easy to operate
- OI software, IPC hardware, all programming as provided by contractor has been replaced with hardware, software, and programming accomplished by St. Louis District.

Table 25 describes the water level indicator.

Table 25. General water level indicator comments on Melvin Price Locks and Dam.

Subject	Comments
Type	Pressure Transmitter
Manufacturer	Druck PTX 1830
Body Material	Titanium
Electronics	No comments
Reliability	They are positioned in a very reliable fashion
Accuracy	0.06% FS

Additional comments about water level indicator:

- There are two transmitters at each location. They compare each other to check upstream/downstream/chamber depths. If they differ by too much, they are checked for malfunction

- The semi-automatic mode, used for essentially all lockages relies on the pressure transducers for operation. They are the most important part of the semi-automatic operating mode and therefore the most important part of the operation of the locks
- A titanium body was specifically chosen due to problems with zebra mussels attaching to the transmitters. Unfortunately the zebra mussels now attach to the dirt that attaches to the titanium.

Table 26 describes the gate position indicator.

Table 26. General gate position indicator comments on Melvin Price Locks and Dam.

Subject	Comments
Type	Rotating shaft position indicators
Manufacturer	Astrosystems, Inc. DuraPot HDC40 PT
Body Material	No comments
Electronics	Direct 4-20 ma output
Reliability	Very reliable; built-in surge and lightning protection
Accuracy	0.05% FS

Additional comment about the lift gate position indicator:

The original Astrosystems transducers have been replaced with units that provide a direct 4-20mA output to the PLC. The original units required encoder electronics that converted the stator phase difference to a current output. The encoders were not adequately protected from lightning surges and were occasionally damaged during severe lightning storms.

Table 27 describes the gate overtravel indicator.

Table 27. General gate overtravel indicator comments on Melvin Price Lock and Dam.

Subject	Comments
Type	Inductive proximity limit switch
Manufacturer	Cutler Hammer E51ALT16PU Form C (Aux lock) Furnas 62C1G2A (Main lock)
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comment about the gate overtravel indicator:

The overtravel limit switches have been modified so that they stop gate movement not only when operated in PLC mode, but also when operated in the hardwired manual mode.

Table 28 describes the change-of-gate-speed indicator.

Table 28. General change-of-gate-speed indicator comments on Melvin Price Locks and Dam.

Subject	Comments
Type	Inductive proximity limit switch
Manufacturer	Cutler Hammer E51ALT16PU (Form A)
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comment about the change-of-gate-speed indicator:

> These switches replaced the original rocker-arm type switches provided under the construction contract. They are non-contact, with no moving parts, and have proven to be reliable once properly adjusted.

Table 29 describes the valve position indicator.

Table 29. General valve position indicator comments on Melvin Price Locks and Dam.

Subject	Comments
Type	Rotating shaft position indicators, absolute resolver type
Manufacturer	Astrosystems HST34-1-1-W-100
Body Material	NEMA 6P
Electronics	Astrosystems BR (UW) 3010-30-3-0 Encoder System
Reliability	It is reliable
Accuracy	It is accurate

Additional comment about the valve position indicator:

> The intermediate position of the valves is only available through the PLC. To insure repeatable position indication, the scale and offset is recalculated for each movement of the valve and is based on the previous movement. This ensures that the percent of opening always falls between 0 and 100 percent.

Table 30 describes the valve overtravel indicator.

Table 30. General valve overtravel indicator comments on Melvin Price Locks and Dam.

Subject	Comments
Type	Inductive proximity limit switch
Manufacturer	Cutler-Hammer E51CLT16U (form C)
Body Material	No comments
Electronics	No comments
Reliability	It is reliable
Accuracy	It is accurate

Additional comment about the valve overtravel indicator:

Originally, the limit switches sensed the position of the bellcrank, but were damaged from ice and debris during high-water conditions. They have been relocated and are now tripped by the tilting motion of the hydraulic cylinder.

Table 31 describes the dam-gate position indicator.

Table 31. General dam-gate position indicator comments (tainter gates) on Melvin Price Locks and Dam.

Subject	Comments
Type	Force Balance Inclinometer
Manufacturer	Columbia Research Laboratory Model SI-701BHP
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	0.2% FS

Additional comment about the tainter gate position indicator:

These are similar to the ones used on Dams 24 and 25 except they produce a voltage output instead of direct 4-20mA output.

Table 32 describes the dam-gate overtravel indicator (tainter gates).

Table 32. General dam-gate overtravel indicator comments (tainter gates) on Melvin Price Locks and Dam.

Subject	Comments
Type	Rotary cam limit switch
Manufacturer	Patriot Sensors & Controls (formerly Gemco Electric)
Body Material	No comments
Electronics	No comments
Reliability	No comments
Accuracy	No comments

Additional comments about the tainter gate overtravel indicator:

None

Table 33 describes the mitered/open indicator.

Table 33. General mitered/open indicator comments on Melvin Price Locks and Dam.

Subject	Comments
Type	Magnetic vane proximity switch, Inductive proximity switch
Manufacturer	GECR115A, Cutler Hammer E51CLT16PU form C
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very reliable

Additional comments about the mitered/opened indicator:

None

Table 34 describes the lift gate motor speed indicator.

Table 34. General lift gate motor speed indicator comments on Melvin Price Locks and Dam.

Subject	Comments
Type	Pulse Encoder
Manufacturer	Encoder Products Company Model 711-0
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about the lift gate motor-speed indicator:

- The pulse encoders keep track of the number of rotations of the lift gate DC motors and adjust the field to speed up or slow down one side of the leaf to automatically correct skew. This is done independently of the PLC
- Each leaf has a separate automatic skew correcting system.

Table 35 describes the CCTV system.

Table 35. General CCTV system comments on Melvin Price Locks and Dam.

Subject	Comments
Purpose	Monitor gates, site perimeter, and chamber water discharge area
Manufacturer	Vicon Industries and Math Associates
Camera	Vicon VC2820A-24
Monitor	Vicon VM6092 (color) and Vicon VM5093 (b&w)
Design	All video is transmitted over fiber optics

Additional comments about the CCTV system:

- All color cameras

- There are 42 cameras and 25 monitors used
- Communications between cameras are carried over copper wire. The chips in the cameras burn up when there is a lightning strike.

Locks No. 27

Granite City, IL, 26 May 1999
Lockmaster — Ed Rogers (618) 452-7107
Electrician — John Tatum (618) 452-7107
Engineer Staff POC — Andy Schimpf (314) 331-8269

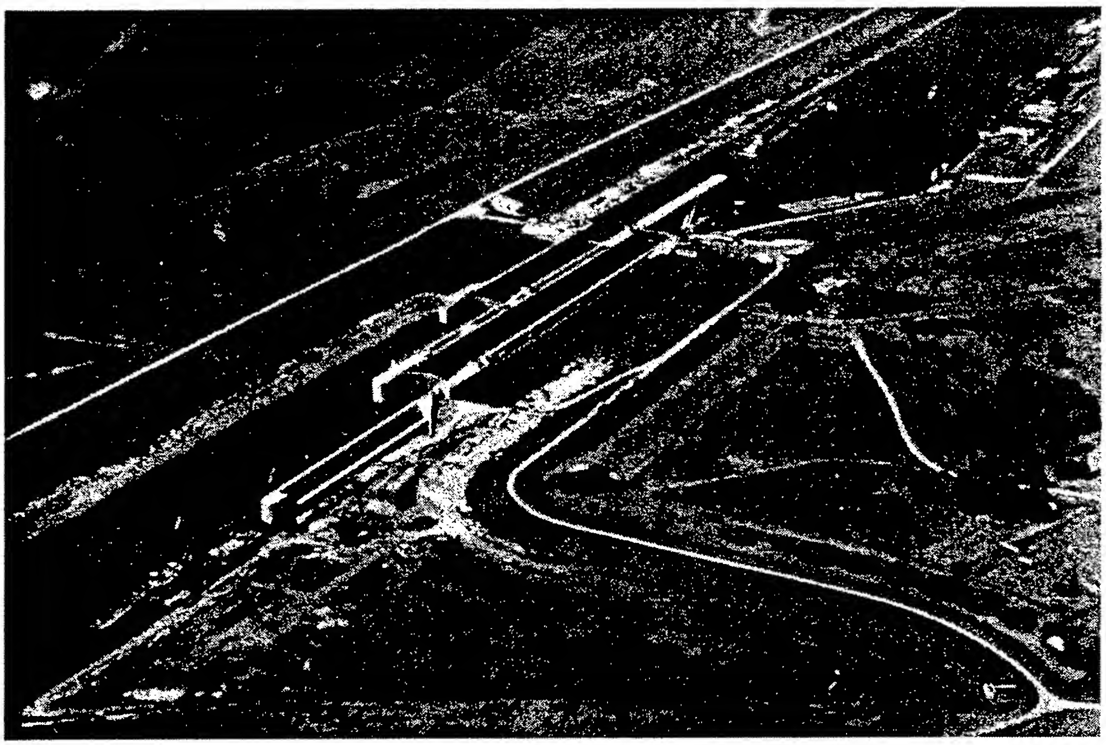


Figure 6. Aerial view of Locks No. 27.

Locks No. 27 is located near Granite City, IL on the Mississippi River. The structure contains two lock chambers. The main lock is 110 ft wide X 1200 ft long. The auxiliary lock is 110 ft wide X 600 ft long. Both the main and auxiliary locks have a two-leaf lift gate on the upstream end and a pair of miter gates on the downstream end. The locks can handle a maximum lift of 19 ft. Rexroth hydraulic units run the miter gates. The lift gates are run by electric motors using Variable Frequency Drives. In 1998, the total traffic of the main and auxiliary locks consisted of more than 8700 lockages for a total of over 80 million tons of cargo.

The control houses used for lock operations are all located on the intermediate or I-wall (i.e., the wall between the two lock chambers). There are three control stations on the I-wall:

- Upper control station (Main and Auxiliary Lock)
- Central control station (Auxiliary Lock)
- Lower control station (Main Lock)

Control of both the upper and lower ends of both lock chambers can be accomplished from the upper control station. However, since visibility of the lower end is limited from the upper end, the middle control station controls the downstream machinery of the auxiliary lock and the lower control station controls the downstream machinery of the main lock.

Lock control in all of the control stations is conducted using the Square D Streamline 2.0 software running on an IPC. A GUI depicting the layout of the lock is displayed on the monitor of the IPC. The lock operator uses a mouse to point and click on the icons corresponding to the desired lock operations. The safety interlocks for lock operations are integrated into the programming of the PLC. In the event of PLC failure, there are hardwired backup systems in place to run all lock machinery. However, this means operation without the benefit of the safety interlocks. The lock has been open for use since 1953. It has been operating exclusively with PLC/OI controls using the Square D 655 processor since its last major rehab in1995.

Table 36 describes the PLC.

Table 36. General PLC comments on Locks No. 27.

Subject	Comments
Input	Limit switches, position transmitters, and pressure transducer
Output	Gate motor VFD's, valve motor drivers, HPU's, lights
Manufacturer	Square D
Processor	SY/MAX 655
Network Design	Windows NT Client/Server
System Design	No comments
PLC Programming Software	STW374

Additional comments about the PLC:

- Using the PLC for troubleshooting and interlock programming is great
- It is the way all locks should go to. The little bit of transition is worth the benefits
- Fiber optic lines run from the IPCs to the PLC
- PLC programming handles safety interlocks

- Skew correction (of lift gates) and safeguards are just a keystroke away via the PLC
- System has operated since 1995 with very few problems
- The PLC control system has variable frequency drives and remote switchable circuit breaker panelboards integrated into the system
- The programming software is easy to learn and use and accommodates all kinds of changes to the ladder logic rungs.

Table 37 describes the OI.

Table 37. General OI comments on Locks No. 27.

Subject	Comments
Type	PC/GUI
Manufacturer	Industrial Computer Source
PC Components	Various Industry Leaders
Monitor	Acer CRT Monitor
Design	No comments
OI Software	Streamline 2.0

Additional comments about the OI:

- Sound capabilities on the IPC for alarms would help lock operators
- The monitors were obsolete at installation and have been nothing but trouble. However, the monitors met the specifications that the contractor bid on at the time.
- Plans are in place to procure new monitors
- Operators have really come to appreciate the reliability and flexibility of the OI control system.

Table 38 describes the water level indicator.

Table 38. General water level indicator comments on Locks No. 27.

Subject	Comments
Type	Pressure transducer
Manufacturer	Druck PTX 168D
Body Material	Titanium
Electronics	No comments
Reliability	It's pretty reliable
Accuracy	0.06% FS

Additional comment about the water level indicator:

Personnel used to "eyeball" the water level and "guesstimate" when chamber level was equal to upstream or downstream pool levels. The pressure transducer provides a true "pools equal" interlock for operating the gates.

Table 39 describes the gate position indicator.

Table 39. General gate position indicator comments (lift gate) on Locks No. 27.

Subject	Comments
Type	Rotating shaft position transmitter, absolute resolver type
Manufacturer	Astrosystems, Inc. Durapot HDC40 PT
Body Material	No comments
Electronics	Direct 4-20 ma output
Reliability	Very reliable; built-in surge and lightning protection
Accuracy	0.05% FS

Additional comment about the lift gate position indicator:

> One side leads and indicates its position while the other corrects its position to match the first.

Table 40 describes the gate position indicator.

Table 40. General gate position indicator comments (miter gate) on Locks No. 27.

Subject	Comments
Type	Ceramax Integrated Measurement Systems
Manufacturer	Rexroth
Body Material	Stainless steel
Electronics	No comments
Reliability	Very reliable
Accuracy	1/1024 cm

Additional comment about the miter gate position indicator:

> There used to be Rexroth black boxes to convert the pulses generated by the CIMS transducer from the rings integrated in the ceramic coating on the rod into position indications which were then transmitted to the PLC. This system was prone to error. In 1998, this system was replaced with a PLC high speed counter card that connects directly to the CIMS transducer. This system has worked well.

Table 41 describes the gate overtravel indicator.

Table 41. General gate overtravel indicator comments on Locks No. 27.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Cutler Hammer
Body Material	Really not suited for lock environment
Electronics	No comments provided
Reliability	They have had all kinds of problems with this device
Accuracy	When it works, it is just an open/closed switch.

Additional comments about the gate overtravel indicator:

None

Table 42 describes the change-of-gate-speed indicator.

Table 42. General change-of-gate-speed indicator comments on Locks No. 27.

Subject	Comments
Type	Ceramax Integrated Measurement Systems
Manufacturer	Rexroth
Body Material	Stainless steel
Electronics	No comments
Reliability	Very reliable
Accuracy	1/1024 cm

Additional comments about the change-of-gate-speed indicator:

None

Table 43 describes the valve position indicator.

Table 43. General valve position indicator comments on Locks No. 27.

Subject	Comments
Type	Traveling nut limit switches
Manufacturer	Cutler Hammer
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comment about the valve overtravel indicator:

During major rehab 1995 – 1996, these limited switches were cleaned, retensioned, and placed back in service as inputs to the PLC control system. This was done because the units have been so reliable for 40 years.

Table 44 describes the valve overtravel indicator.

Table 44. General valve overtravel indicator comments on Locks No. 27.

Subject	Comments
Type	Vane Operated limit switches
Manufacturer	Cutler Hammer
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comment about the valve overtravel indicator:

> During major rehab 1995 – 1996, these limited switches were cleaned, retensioned, and placed back in service as inputs to the PLC control system. This was done because the units have been so reliable for 40 years.

Table 45 describes the mitered/open indicator.

Table 45. General mitered/open indicator comments on Locks No. 27.

Subject	Comments
Type	Magnetic vane proximity limit switch
Manufacturer	General Electric Model #CR115A58AF
Body Material	No comments
Electronics	No comments
Reliability	It is pretty reliable
Accuracy	Very accurate once calibrated

Additional comments about the mitered/opened indicator:

- These switches are also used to calibrate the CIMS system
- They require occasional recalibration because they give a little due to temperature fluctuations.

Nashville District Locks (CELRN)

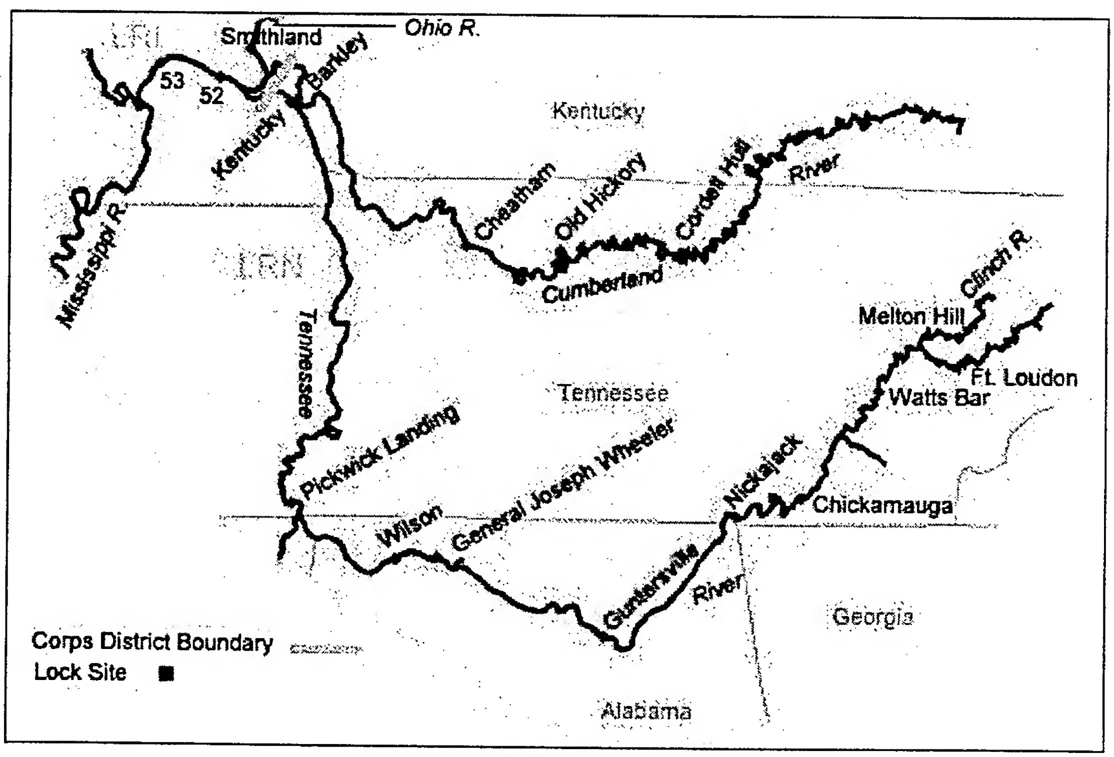


Figure 7. Locations of Nashville District Locks visited.

The Nashville District includes 59,000 square miles of land and touches seven states. Navigation, hydropower, environmental management, and flood control are some of the water resource related tasks undertaken by the district.

The four locks in the Nashville District that are included in this study are Barkley Lock and Dam, General Joe Wheeler Auxiliary Lock, Wilson Locks (Main and Auxiliary), and Pickwick Landing Auxiliary Lock. These locks operate under the highest lifts of all the sites. The control systems at these locks represent the full gamut of possibilities that have been encountered. In fact, Barkley Lock is the only lock in the Corps capable of on-site wireless-controlled full lockage, which was demonstrated during the site visit. Wilson Main Lock is the only lock in the Corps whose PLC system is not either an Allen Bradley or Square D product; it uses a Reliance Automax Distributed PLC System.

Barkley Lock

Grand Rivers, KY, 18 February 1999 and 2-3 August 1999
Lockmaster — Gerald Cunningham (502) 362-9131
Operations Engineer — Richard Nimmo (615) 736-5971
Electrician — Jerry Wisdom (503) 362-9131

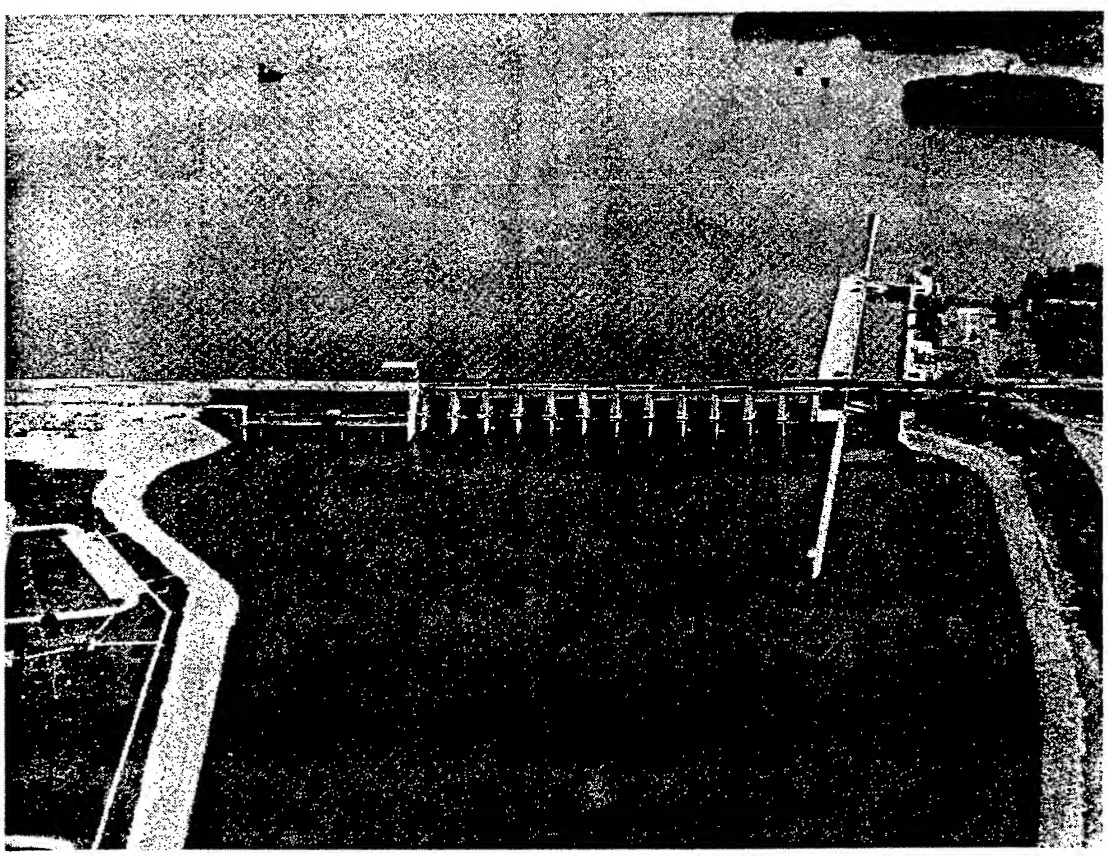


Figure 8. Aerial view of Barkley Dam and Lake Barkley.

The lock at Barkley Dam and Lake Barkley is located in Lyon and Livingston Counties, Kentucky, on the Cumberland River about 30.6 miles above its confluence with the Ohio River. The lock chamber is 110 ft wide X 800 ft long. Land and River hydraulic units drive the miter gate and culvert valve machinery. The lock can handle a maximum lift of 73 ft. The normal lift is 56 ft. In 1998, traffic at the lock consisted of 2819 lockages for a total over 9.6 million tons of cargo.

The lock operates under manual control via the PLC system. There is a control station at each end of the lock capable of controlling the lock machinery at that end. The primary operator interface in the control stations is a pushbutton control panel. Pushbutton signals are input directly into the PLC to initiate operation commands. The safety interlocks for lock operations are integrated into the programming of the PLC. Control of the tow haulage system is accomplished via the Modicon PanelMate LCD OI.

Barkley lock has the special distinction of being the first lock in the country to effect on-site radio remote lock control. With the aid of DataLinc modems acquired for them by CERL, the Nashville District personnel were able to integrate all of the lock operations feedback data and controls provided by the PLC system with the Modicon PanelMate 1000 portable operator interface. The PanelMate units originally were procured as a means of operating the tow haulage system and displaying the pool level information transmitted to the PLC by the pressure transducers at the lock.

The lock was opened for use in 1964. It has been operating with PLC-based controls since 1990. The new PanelMate Display System was added in 1996 with the replacement of the tow haulage equipment. At the same time a minimal hardwired back-up control system was implemented for use in the event of PLC system failure.

Table 46 describes the PLC.

Table 46. General PLC comments on Barkley Lock.

Subject	Comments
Input	Position transmitters, limit switches, pressure transducers, thermocouples
Output	Hydraulic pump drivers, air horn, tow-haulage commands
Manufacturer	Square D
Processor	Square SY/MAX 400
Network Design	Square D SY/MAX RS 422 Protocol originally via dual twisted shielded cable with surge protectors. Main I/O commo lines were upgraded to fiber optics in 1993.
System Design	No comments
PLC Programming Software	Square D SY/MATE SFW 374 DOS Based Programming

Additional comments about the PLC:

- Originally installed the SY/MAX 500 processor, but upgraded to the 400 model for floating point arithmetic functions and larger memory
- The CPU has 2 communications ports
- One or two remote interface modules have had to be replaced since the PLC control system has been in use
- There were lightning strikes in 1992. At that time, MCG surge protection was in place on the standard twisted pair shielded cable RS422 communication links: several cards and the phone system were damaged
- Fiber optic communication lines were installed and the PLC system has not been affected by lightning since; although the copper wire-based phone system has failed as a result of lighting strikes
- There is no UPS in place; instead a battery pack consisting of 3 D-cell batteries that is replaced every three months provides continuous backup power in case of an outage.

Table 47 describes the OI.

Table 47. General OI comments on Barkley Lock.

Subject	Comments
Type	Modicon PanelMate 1000 (5 inch monochrome LCD Display)
Manufacturer	Modicon/Square D
PC Components	N/A
Monitor	It is compact, portable, and very handy
Design	NEMA 4 Construction
OI Software	Modicon DOS–Based Screen Programming via PC; it's relatively easy to program and efficient

Additional comments about the OI:

- It interfaces with the PLC processor via a network card
- It performs the following tasks:
  - Displays upstream/downstream/chamber water level
  - Displays hydraulic pressure
  - Receives security system info from the PLC and displays it
  - Displays status of all lock operations (gates, valves, air compressor, etc.)
- Long range remote control of all lock operations (full lockage procedure was demonstrated from over a mile away)
- Controls the tow haulage unit
- Its user interface is an excellent, inexpensive, and robust means of lock control
- It allows lock operators to get out of the control booth for better visibility of lock chamber
- It encompasses all the functionality of the control panel and/or an OI in a portable form at a relatively low cost.

Table 48 describes the water level indicator.

Table 48. General water level indicator comments on Barkley Lock.

Subject	Comments
Type	Pressure transmitter
Manufacturer	Druck PTX 161 and Endress-Hauser deltapilot SDB53A
Body Material	No comments
Electronics	No comments
Reliability	The Endress-Hauser transmitters have proven more reliable than the Druck models
Accuracy	Both models are very accurate when calibrated

Additional comments about the water level indicator:

- The Endress-Hauser pressure transducer replaced the Druck pressure transducer, and has been in operation for a year with no sign of drifting in its output
- The Druck models have required quarterly recalibration due to drift during regular operation, and in times of high lockage volume, monthly recalibration is required.

Table 49 describes the gate position indicator.

Table 49. General gate position indicator comments on Barkley Lock.

Subject	Comments
Type	Rotary Position Transmitter and Switch
Manufacturer	Proximity Controls Model #35AD1
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about the miter gate position indicator:

None

Table 50 describes the change-of-gate-speed indicator.

Table 50. General change-of-gate-speed indicator comments on Barkley Lock.

Subject	Comments
Type	Rotary Position Transmitter and Switch
Manufacturer	Proximity Controls Model #35AD1
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about the change-of-gate-speed indicator:

None

Table 51 describes the valve position indicator.

Table 51. General valve position indicator comments on Barkley Lock.

Subject	Comments
Type	Rotary Position Transmitter and Switch
Manufacturer	Proximity Controls Model #35AD1
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about the valve position indicator:

None

Table 52 describes the mitered/open indicator.

Table 52. General mitered/open indicator comments on Barkley Lock.

Subject	Comments
Type	Magnetic vane proximity switch
Manufacturer	General Electric Model #CR115A11
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very reliable

Additional comments about the gate opened/mitered indicator:

None

Table 53 describes the CCTV system.

Table 53. General CCTV system comments on Barkley Lock.

Subject	Comments
Purpose	Monitoring of lock traffic and facility grounds
Camera	Phillips LTC 0500 Digital Monochrome Camera
Camera Housing	Burle TC9340A Weatherproof Environmental Housing-Medium
Monitor	Phillips LTC 2009 Series 9" Monochrome Video Monitor
Design	1 controller is not working

Additional comments about the CCTV system:

- Having some trouble getting spare parts for CCTV system
- At the time of the visit, Phillips had recently acquired Burle.

General Joe Wheeler Auxiliary Locks

Wheeler Dam Village, AL, 22 June 1999
Lockmaster — Gary Bowling (205) 247-3311
Project Engineer — Richard Nimmo (615) 736-5971
Engineer Staff POC — Marlin Wells (615) 736-5971

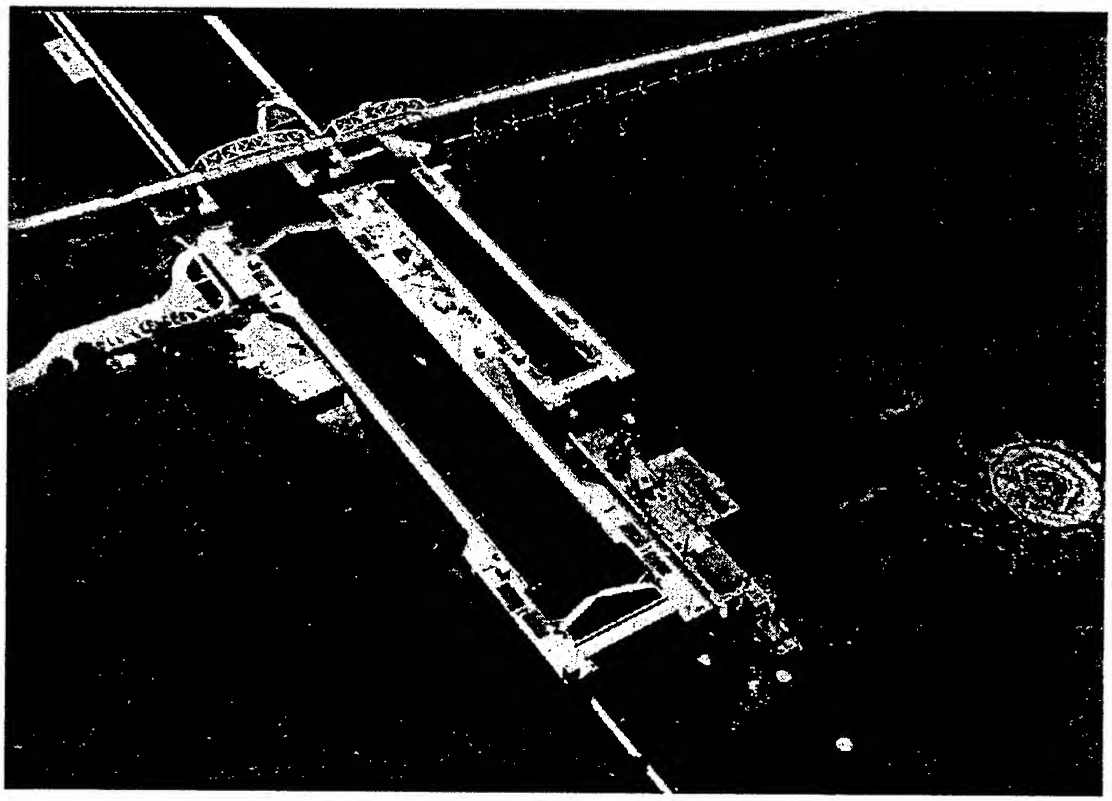


Figure 9. Aerial view of General Joe Wheeler Main and Auxiliary Locks.

The General Joseph Wheeler Lock and Dam has two lock chambers. The main lock is 110 ft wide X 600 ft long, and the auxiliary lock is 60 ft wide X 400 ft long. The normal lift at the lock is about 48 ft. Individual hydraulic units run the miter gate machinery in the auxiliary lock. The auxiliary culvert valve machinery is electric motor gear reduction type. The main lock miter gate and culvert valve machinery are all individual electric motor gear reduction type. In 1998, the total traffic of the main and auxiliary locks consisted of more than 3284 lockages for a total over 14.3 million tons of cargo.

There are local control stations at each end of each lock capable of controlling the lock machinery at that end of the lock. Control of the main lock is accomplished via hardwired relays. The auxiliary lock operates under manual control via the PLC system. The primary operator interface in the control stations is a pushbutton control panel. Pushbutton signals are input directly into the PLC to initiate operation commands. The safety interlocks for lock operations are integrated into the programming of the PLC. There is also a separate hardwired interlock system and a hardwired manual back-up system.

The lock was opened for use in 1934. The auxiliary lock has been operating under PLC control since 1984. The auxiliary lock miter gate machinery was replaced with direct acting hydraulic cylinders and individual power units in 1996.

Table 54 describes the PLC.

Table 54. General PLC comments on Wheeler Auxiliary Locks.

Subject	Comments
Input	Position indicators, limit switches
Output	Gate pump drivers, valve pump drivers
Manufacturer	Square D
Processor	Square D SY/MAX 400
PLC Network Design	Square D SY/MAX RS 422 protocol via dual twisted shielded cable with surge protectors.
System Design	No comments
PLC Programming Software	Square D SY/MAX SFW 374

Additional comments about the PLC:

None

Table 55 describes the OI.

Table 55. General OI comments on Wheeler Auxiliary Locks.

Subject	Comments
Type	Standard pushbutton control panel hardwired to PLC racks
Manufacturer	Square D (pushbuttons)
PC Components	N/A
Monitor	N/A
Design	It looks almost identical to the relay-based main lock control panels; the operators like it
OI Software	N/A

Additional comments about the OI System:

None

Table 56 describes the water level indicator.

Table 56. General water level indicator comments on Wheeler Auxiliary Locks.

Subject	Comments
Type	Pressure transmitter
Manufacturer	Druck PTX 161D or 160D
Body Material	No comments
Electronics	No comments
Reliability	Pretty reliable
Accuracy	Pretty accurate

Additional comments about the water level indicator:

- Have not had to replace the Druck transducers very often
- When the headwater fluctuates significantly, the Drucks have to be recalibrated.

Table 57 describes the gate position indicator.

Table 57. General gate position indicator comments on Wheeler Auxiliary Locks.

Subject	Comments
Type	Cable-extension linear position transmitter
Manufacturer	Celesco Model #PT9420
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comment about the miter gate position indicator:

> One of the position indicators was inoperative at the time of the visit, but the lockmaster did not consider it necessary to get it repaired, as the operators can just look out and see what position the gate is in between fully mitered and fully recessed.

Table 58 describes the valve position indicator.

Table 58. General valve position indicator comments on Wheeler Auxiliary Locks.

Subject	Comments
Type	Selsyn-type rotary position transmitters
Manufacturer	Henschel Corp. Model #10-1052-2
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about the valve position indicator:

None

Table 59 describes the mitered/open indicator.

Table 59. General mitered/open indicator comments on Wheeler Auxiliary Locks.

Subject	Comments
Type	Magnetic vane proximity switch
Manufacturer	General Electric Model #GECR115A11
Body Material	No comments
Electronics	No comments
Reliability	No comments
Accuracy	No comments

Additional comments about the gate mitered/recessed indicator:

None

Table 60 describes the change-of-gate-speed indicator.

Table 60. General change-of-gate-speed indicator comments on Wheeler Auxiliary Locks.

Subject	Comments
Type	Cable-extension linear position transmitters
Manufacturer	Celesco Model #PT9420
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about the change-of-gate-speed indicator:

None

Table 61 describes the CCTV system.

Table 61. General CCTV system comments on Wheeler Auxiliary Locks.

Subject	Comments
Purpose	Monitoring of the lock's water discharge area
Camera	Phillips LTC 0500 Digital Monochrome Camera
Camera Housing	Burle TC9340A Weatherproof Environmental Housing-Medium
Monitor	Phillips LTC 2009 Series 9" Monochrome Video Monitor
Design	1 controller is not working

Additional comments about the CCTV system:

None

Wilson Main and Auxiliary Locks

Florence, AL, 21 June 1999
Lockmaster — Gary Harding (256) 764-5226
Engineer Staff POC — Marlin Wells (615) 736 5971
Electrician — Kenneth Rhodes (256) 764-5226

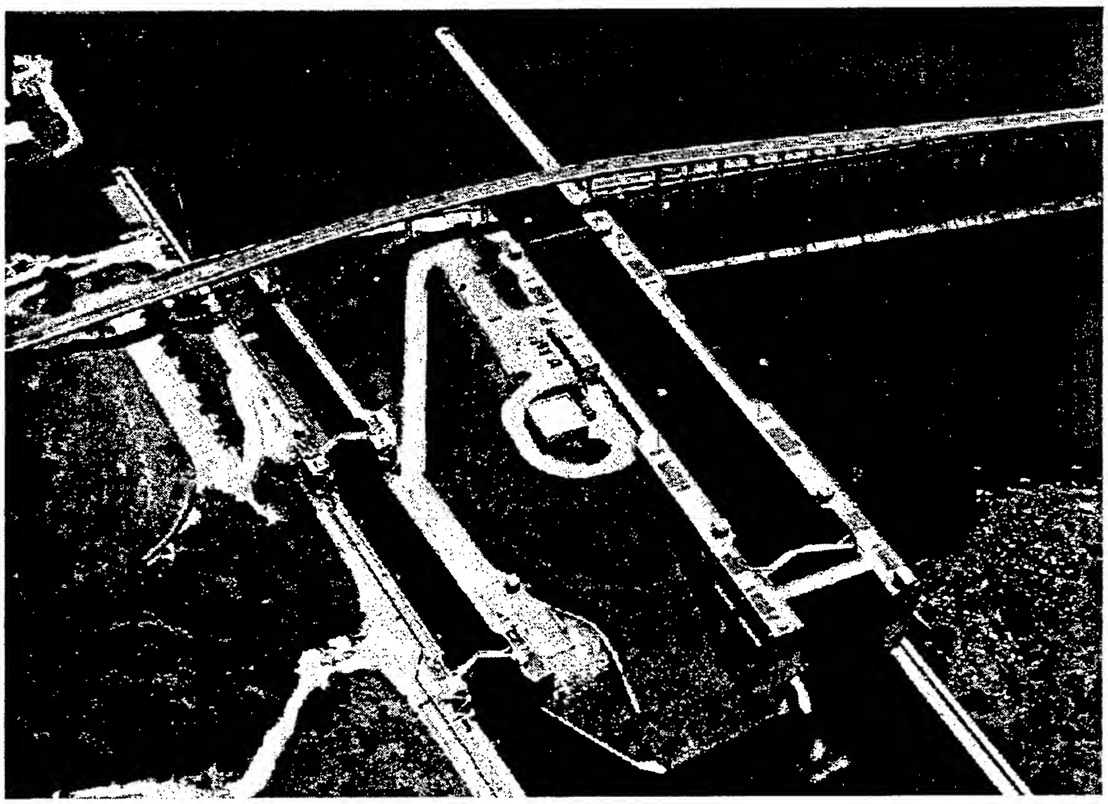


Figure 10. Aerial view of Wilson Main and Auxiliary Locks.

The Wilson Locks and Dam is located 2.9 miles above the railroad bridge at Florence, Alabama. It serves to secure a channel depth of at least 9.5 ft at extreme low water for a distance of 14.7 miles. It also serves to generate electrical power for the production of nitrates or other products useful in the manufacture of fertilizers and other useful products. The main lock is 110 ft wide X 600 ft long, and the auxiliary lock is a double lock with two 60 ft wide X 300 ft chambers. In 1998, traffic at the lock consisted of 3039 lockages for a total of over 14.6 million tons of cargo. Both the main and auxiliary locks are controlled by PLC systems. The locks normally operate under a 90 ft head.

Auxiliary Lock

The auxiliary lock uses Square D PLC equipment similar to that used at other locks surveyed for this report. It is very seldom used, normally only when the main lock is out of operation. The auxiliary lock is a two stage lock with a lift gate on the upstream end of the first chamber and miter gates at the upstream and downstream ends of the second chamber. The gates and one culvert valve are operated by electric motors. The upper chamber hydraulic valves are hydraulically operated.

Main Lock

The main lock is a single stage lock with a lift gate on the upstream end and a pair of miter gates on the downstream end. The control system of the main lock at Wilson is distinguished by the fact that it is characterized as a multitasking distributed control system in contrast with the standard PLC systems in use on the auxiliary lock and all the other locks studied. The main difference in this control system is that each node in the control network has an independent processor that has its own programming and functions. The standard PLC system is distinguished by the fact that it consists of a central processing unit that receives and transmits data from and to the other nodes in the network. The operator interface at Wilson also distinguishes it from the other locks surveyed. Wilson operates with parallel PLC control comprised of both a pushbutton control panel and a GUI-driven control panel, wired into the PLC. The operator can use either system to interact with the full complement of feedback and control information provided by the PLC system, which was installed in 1996. The culvert valves have electric motor gear reduction machinery.

Table 62 describes the PLC.

Table 62. General PLC comments on Wilson (main) Lock.

Subject	Comments
Input	Pool level indicator, gate switches, gate/valve resolvers
Output	Gate motor drivers, valve motor drivers
Manufacturer	Reliance Electric Automax Distributed Control System
Processor	57C435 Automax Processor 7010
Network Design	It's a distributed control system with a central location that all communications runs through.
System Design	Reliance makes modules specifically to receive data from resolvers. All communications is carried on fiber-optic lines. Maintenance is able to do remote debugging.
PLC Programming Software	Automax Executive Software by Reliance-It's great.

Additional comments about the PLC:

- The distributed control system is multitasking, handles more data, and allows prioritization of tasks
- Each processor has its own ladder program in its memory
- There are four quadrants at the main lock each with its own processor in the rack
- Each rack also holds a Reliance universal drive controller module to drive the equipment at that location
- There is one hub that all communications goes through
- The programs for each quadrant are different and are stored on a laptop and on a diskette.

Table 63 describes the OI.

Table 63. General OI comments on Wilson (main) Lock.

Subject	Comments
Type	Proprietary console with monitor and processor built into one unit and pushbutton parallel control panel
Manufacturer	Computer Technology Corporation (CTC) Toolbox with Interact 4.0
PC Components	Proprietary to CTC
Monitor	Proprietary to CTC
Design	The control panel consists of the CTC unit next to a standard pushbutton control console
OI Software	CTC Interact 4.0

Additional comments about the OI:

- The parallel control was used due to the fact that a software-based OI had not been proven at the time of the last major rehab.
- Operators use both the pushbutton control panel and the GUI-driven control panel interchangeably.

Table 64 describes the water level indicator.

Table 64. General water level indicator comments on Wilson (main) Lock.

Subject	Comments
Type	Reflected wave
Manufacturer	Celtek Electronics, Inc. LM7000 Level monitor
Body Material	No comments provided
Electronics	No comments provided
Reliability	It is reliable
Accuracy	It is accurate

Additional comments about the water level indicator:

None

Table 65 describes the gate position indicator.

Table 65. General gate position indicator comments on Wilson (main) Lock upstream.

Subject	Comments
Type	Resolver
Manufacturer	BRX FA-Solver Type 800123-R
Body Material	No comments provided
Electronics	No comments provided
Reliability	It is reliable
Accuracy	It is accurate, more accurate than need be.

Additional comment about the lift gate position indicator:

At the upstream end, the main lock has a lift gate. This introduces the problem of having to regulate the skew of the gate as it travels up and down. The resolver handles this very well.

Additional comments about the miter gate position indicator:

None

Table 66 describes the gate position indicator.

Table 66. General gate position indicator comments on Wilson (main) Lock downstream.

Subject	Comments
Type	Resolver
Manufacturer	BRX FA-Solver Type 800123-R
Body Material	No comments provided
Electronics	No comments provided
Reliability	It is reliable
Accuracy	It is accurate, more accurate than need be

Additional comments about the gate position indicator:

None

Table 67 describes the gate overtravel indicator.

Table 67. General gate overtravel indicator comments on Wilson (main) Lock.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Cutler Hammer E50 6P E50SB6P20
Body Material	No comments provided
Electronics	No comments provided
Reliability	It is reliable
Accuracy	It is accurate

Additional comment about the gate overtravel indicator:

> The E50 limit switch came with a flexible contact arm that was susceptible to becoming deformed during use. To alleviate this, that arm was exchanged for a longer more rigid contact attachment.

Table 68 describes the change-of-gate-speed indicator.

Table 68. General change-of-gate-speed indicator comments on Wilson (main) Lock.

Subject	Comments
Type	Resolver
Manufacturer	BRX FA-Solver Type 800123-S
Body Material	No comments provided
Electronics	No comments provided
Reliability	It is reliable
Accuracy	It is accurate, more accurate than need be

Additional comment about the change-of-gate-speed indicator:

> There are two resolvers on the upstream and downstream ends — one to indicate gate position and another to indicate speed.

Table 69 describes the valve position indicator.

Table 69. General valve position indicator comments on Wilson (main) Lock.

Subject	Comments
Type	Resolver
Manufacturer	BRX FA-Solver Type 800123-R
Body Material	No comments provided
Electronics	No comments provided
Reliability	It is reliable
Accuracy	It is more accurate than need be

Additional comments about the valve position indicator:

None

Table 70 describes the valve overtravel indicator.

Table 70. General valve overtravel indicator comments on Wilson (main) Lock.

Subject	Comments
Type	Magnetic proximity switch
Manufacturer	Scientific Technologies Incorporated Guard Master FRS-6
Body Material	No comments provided
Electronics	No comments provided
Reliability	It is reliable
Accuracy	It is accurate

Additional comments about the valve overtravel indicator:

None

Table 71 describes the mitered/open indicator.

Table 71. General mitered/open indicator comments on Wilson (main) Lock.

Subject	Comments
Type	Magnetic vane proximity switch
Manufacturer	General Electric Model #CR115A11
Body Material	No comments provided
Electronics	No comments provided
Reliability	It is reliable
Accuracy	It is accurate

Additional comments about the gate mitered/open indicator:

None

Table 72 describes the CCTV system.

Table 72. General CCTV system comments on Wilson (main) Lock.

Subject	Comments
Purpose	Monitoring of lock traffic and facility grounds
Camera	Phillips LTC 0500 Digital Monochrome Camera
Camera Housing	Burle TC9340A Weatherproof Environmental Housing-Medium
Monitor	Phillips LTC 2009 Series 9" Monochrome Video Monitor
Design	No comments

Additional comments about the CCTV system:

None

Table 73 describes the PLC.

Table 73. General PLC comments on Wilson (auxiliary) Lock.

Subject	Comments
Input	Position indicators, limit switches
Output	Gate pump drivers, valve pump drivers
Manufacturer	Square D
Processor	Square D SY/MAX 400
PLC Network Design	Square D SY/MAX RS 422 protocol via dual twisted shielded cable with surge protectors.
System Design	No comments
PLC Programming Software	Square D SY/MAX SYMATE SFW 374

Additional comments about the PLCs:

- Have had same PLC components since 1986
- System has battery backed memory
- There is no ethernet connection, one serial port, and one parallel port on the processor
- There is only one processor at the auxiliary lock
- There is a communications hub
- All communications are over shielded cable (i.e., there is no fiber optic line).

Table 74 describes the OI.

Table 74. General OI comments on Wilson (auxiliary) Lock.

Subject	Comments
Type	Standard pushbutton control panel hardwired to PLC racks
Manufacturer	Square D (pushbuttons)
PC Components	N/A
Monitor	N/A
Design	It looks almost identical to the relay-based main lock control panels; the operators like it
OI Software	N/A

Additional comments about the OI:

None

Table 75 describes the water level indicator.

Table 75. General water level indicator comments on Wilson (auxiliary) Lock.

Subject	Comments
Type	Pressure transmitter
Manufacturer	Druck PTX 161D or 160D
Body Material	No comments
Electronics	No comments
Reliability	Pretty reliable
Accuracy	Pretty accurate

Additional comments about the water level indicator:

> The display for the pressure transmitters is a Wyse monitor. These monitors proved to be unreliable, so effectively there is no electronic water level indication for the auxiliary lock.

Table 76 describes the gate position indicator.

Table 76. General gate position indicator comments on Wilson (auxiliary) Lock.

Subject	Comments
Type	Selsyn type rotary position transmitter
Manufacturer	Henschel Model 10-1052-2
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about the gate position indicator:

The upper end is a lift gate whose motion is as follows:

<u>Lowering</u>

- Gate up off of latches
- Retract latches
- Gate down

<u>Raising</u>

- Gate lifts up above latches
- Extend latches
- Gate down upon the latches

Table 77 describes the valve position indicator.

Table 77. General valve position indicator comments on Wilson (auxiliary) Lock.

Subject	Comments
Type	Selsyn-type rotary position transmitters
Manufacturer	Henschel Corp. Model #10-1052-2
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about the valve position indicator:

None

Table 78 describes the mitered/open indicator.

Table 78. General mitered/open indicator comments on Wilson (auxiliary) Lock.

Subject	Comments
Type	Magnetic vane proximity switch
Manufacturer	General Electric Model #GECR115A11
Body Material	No comments
Electronics	No comments
Reliability	No comments
Accuracy	No comments

Additional comments about the gate mitered/open indicator:

None

Note: The Wilson Auxiliary Lock uses single-speed gates, so there is no change-of-gate-speed indicator.

Table 79 describes the CCTV system.

Table 79. General CCTV system comments on Wilson (auxiliary) Lock.

Subject	Comments
Purpose	Monitoring of Bascule Bridge Area and lock's water discharge area
Camera	Phillips LTC 0500 Digital Monochrome Camera
Camera Housing	Burle TC9340A Weatherproof Environmental Housing-Medium
Monitor	Phillips LTC 2009 Series 9" Monochrome Video Monitor
Design	No comments provided

Additional comments about the CCTV system:

None

Pickwick Landing Locks (Auxiliary Lock)

Pyburn, TN, 21 June 1999
Lockmaster — Donnie Damon (901) 925-2334
Engineer Staff POC — Marlin Wells (615) 736-5971
Electrician — Ron Barnes (901) 925-2334

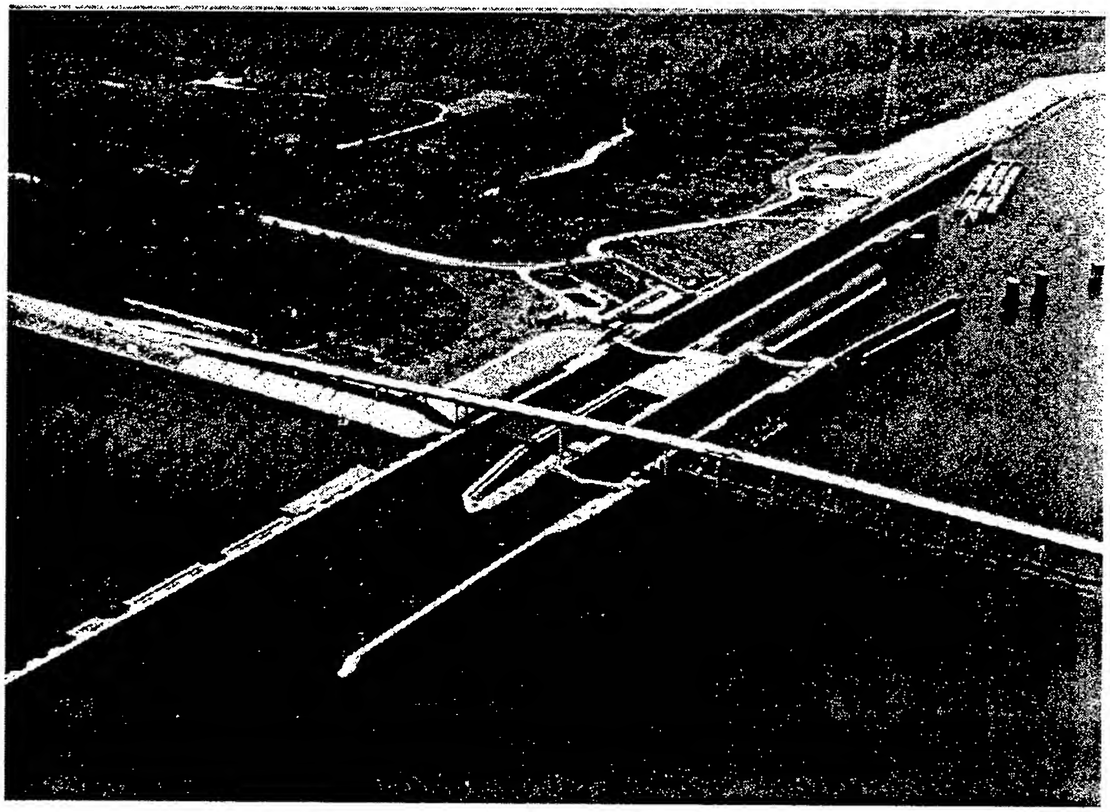


Figure 11. Aerial view of Pickwick Landing Lock and Dam.

There are two locks at Pickwick Landing Lock and Dam. The main lock is 110 ft wide X 1200 ft long, and the auxiliary lock 110 ft wide X 600 ft long. The lock normally operates under a 50 ft lift. In 1998, the total traffic of the main and auxiliary locks consisted of more than 4200 lockages for a total over 23 million tons of cargo. Only the Auxiliary Lock is PLC-controlled.

There are two local control houses on the river wall of the auxiliary lock. The downstream control house can control the equipment on the downstream end of the lock as well as the tow haulage machinery and upper culvert valves. It has

miter gates that are operated by sector track gear and hydraulic rams at both ends and is controlled by a PLC system.

The PLC system also controls the Eaton tow-haulage system. This arrangement has been the source of some trouble due to the fact that the control system that came with the tow-haulage unit was not intended to interface with any other type of control. The lock has been operating with a Square D PLC control system since 1986. Initially the system operated with the Square D 500 Processor. The Square D 400 processor was installed about 5 years ago.

If the PLC system should malfunction for some reason, there is no hardwired backup for operations control. Lock operation is still possible, but without the normal hardwired interlocks.

Table 80 describes the PLC.

Table 80. General PLC comments on Pickwick Landing Locks.

Subject	Comments
Input	Limit switches
Output	Hydraulic motor drivers, valve motor drivers, tow haulage unit driver
Manufacturer	Square D
Processor	SY/MAX 400 (has been in use about 5 years)
Network Design	SY/MAX RS 422 Protocol via dual twisted shielded cable
System Design	No comments
PLC Programming Software	The Square D SY/MAX Programmer came with the system. It houses the programming software; Square D SYMATE SFW 374 DOS-based programming software via PC

Additional comments about the PLC:

- The SY/MAX 500 processor that came on the initial installation of the PLC control system was physically larger than the SY/MAX 400 process that is in use now
- The EAZY SP_SLP-4 surge protector that came on the initial installation was unreliable
- A Square D 8030 CBP surge protector is currently in use and has been very reliable
- The technical support from Square D for troubleshooting and programming has been excellent
- There is no hardwired back up control system. As a result, if the PLC goes down, someone has to be the driver of the various components and physically make the contacts to start the motors
- The tow haulage system is interfaced through the PLC. However, the Eaton engineers who designed the tow haulage unit concluded that since their sys-

tems was not designed to interface with a PLC, the two cannot effectively work together. The PLC can be used to control tow haulage, but the process is unreliable and dangerous.

Table 81 describes the OI.

Table 81. General OI comments on Pickwick Landing Locks.

Subject	Comments
Type	Pushbutton control panel
Manufacturer	
PC Components	N/A
Monitor	N/A
Design	The OI is the same as the original control panel with the modification that all the buttons send input signals to the I/O rack which transmits/receives signals from the PLC and transmits signals to the motor drivers
OI Software	N/A

Additional comments about the OI:

None

Table 82 describes the water level indicator.

Table 82. General water level indicator comments on Pickwick Landing Locks.

Subject	Comments
Type	Tile gauges on lock wall
Manufacturer	N/A
Body Material	N/A
Electronics	N/A
Reliability	As reliable as the operator's eyes
Accuracy	As accurate as the operator's judgment

Additional comments about the water level indicator:

- Druck pressure transmitters (PTX 161D) tied into the PLC had been used, but they were prone to failure, and have been replaced with Druck PTX 1830 type
- The cost of repair is comparable to the cost to purchase new units
- It was suggested that the chemicals in the water could be corrupting the sensors on the old pressure transmitters
- At the time of the visit, personnel at this Lock had not found a way to effectively recalibrate Druck pressure transducers
- The Drucks do not perform well in the humid environments without an extra desiccant filter.

Table 83 describes the gate position indicator.

Table 83. General gate position indicator comments on Pickwick Landing Locks.

Subject	Comments
Type	Gear box mechanism mounted atop the bull gear
Manufacturer	N/A
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comment about the miter gate position indicator:

> As the sector gear turns, it turns the gear on the Henschel-Selsyn type positioning mechanism, which is calibrated to send a signal indicating how far it has turned, which indicates how far the gate has traveled.

Table 84 describes the valve overtravel indicator.

Table 84. General valve overtravel indicator comments on Pickwick Landing Locks.

Subject	Comments
Type	Gear box mechanism mounted atop the bull gear
Manufacturer	N/A
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about the valve overtravel indicator:

> None

Table 85 describes the change-of-gate-speed indicator.

Table 85. General change-of-gate-speed indicator comments on Pickwick Landing Locks.

Subject	Comments
Type	Magnetic vane proximity limit switches
Manufacturer	General Electric Model #CR115A11
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about the change-of-gate-speed indicator:

- They initiate speed changes and stopping

- The hydraulic pump has a bypass condition in the case of overtravel (i.e., overpressure)
- There is no brake on a hydraulic motor, so there is no risk of equipment damage due to overtravel, which is a concern with electric motors.

Table 86 describes valve position indicator.

Table 86. General valve position indicator comments on Pickwick Landing Locks.

Subject	Comments
Type	Gear box mechanism mounted atop the bull gear
Manufacturer	N/A
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about the valve position indicator:

None

Table 87 describes the valve overtravel indicator.

Table 87. General valve overtravel indicator comments on Pickwick Landing Locks.

Subject	Comments
Type	Gear box mechanism mounted atop the bull gear
Manufacturer	N/A
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about the valve overtravel indicator:

None

Table 88 describes the mitered/open indicator.

Table 88. General mitered/open indicator comments on Pickwick Landing Locks.

Subject	Comments
Type	Magnetic vane proximity switches
Manufacturer	General Electric Model #CR115A11
Body Material	No comments
Electronics	No comments
Reliability	No comments
Accuracy	No comments

Additional comments about the gate mitered/open indicator:

None

Table 89 describes the CCTV system.

Table 89. General CCTV system comments on Pickwick Landing Locks.

Subject	Comments
Purpose	Monitoring of lock traffic and facility grounds
Camera	Phillips LTC 0500 Digital Monochrome Camera
Camera Housing	Burle TC9340A Weatherproof Environmental Housing-Medium
Monitor	Phillips LTC 2009 Series 9" Monochrome Video Monitor
Design	No comments

Additional comments about the CCTV system:

None

New Orleans District Locks (CEMVN)

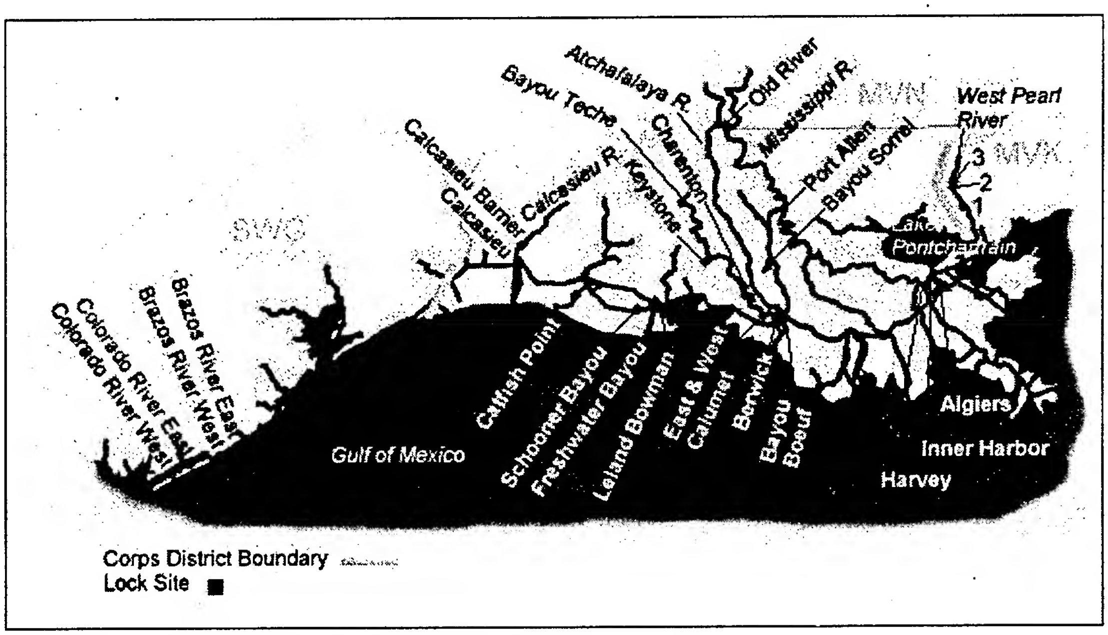


Figure 12. Locations of New Orleans District Locks visited.

The New Orleans District of the U.S. Army Corps of Engineers plans, designs, constructs, operates, and maintains Federally sponsored navigation, flood control, hurricane protection, and water resources development projects in 30,000 square miles of south central and coastal Louisiana. The district's jurisdiction includes more than 2,800 miles of navigable waterways, 950 miles of levees and

floodwalls, 12 navigation locks, six major flood control structures, one freshwater diversion structure, and other projects to protect and enhance the coastal and inland wetlands of Louisiana. The district regulates activities in navigation channels and wetlands, and provides real estate and engineering consultant support for other government agencies.

Two locks from the New Orleans District are included: Leland-Bowman Lock and Calcasieu Lock. Along with Port St. Lucie Lock in the Jacksonville District, these are the only Corps locks with PLCs controls that do not use valve systems to raise and lower the water level in the lock chamber. The lifts experienced at these locks are the smallest of all the sites visited.

Leland-Bowman Lock

Freshwater Bayou, LA, 15 March 1999
Lockmaster — Harold Trahan (318) 893-6790
Engineer Staff POC — Mike Park (504) 862-2302

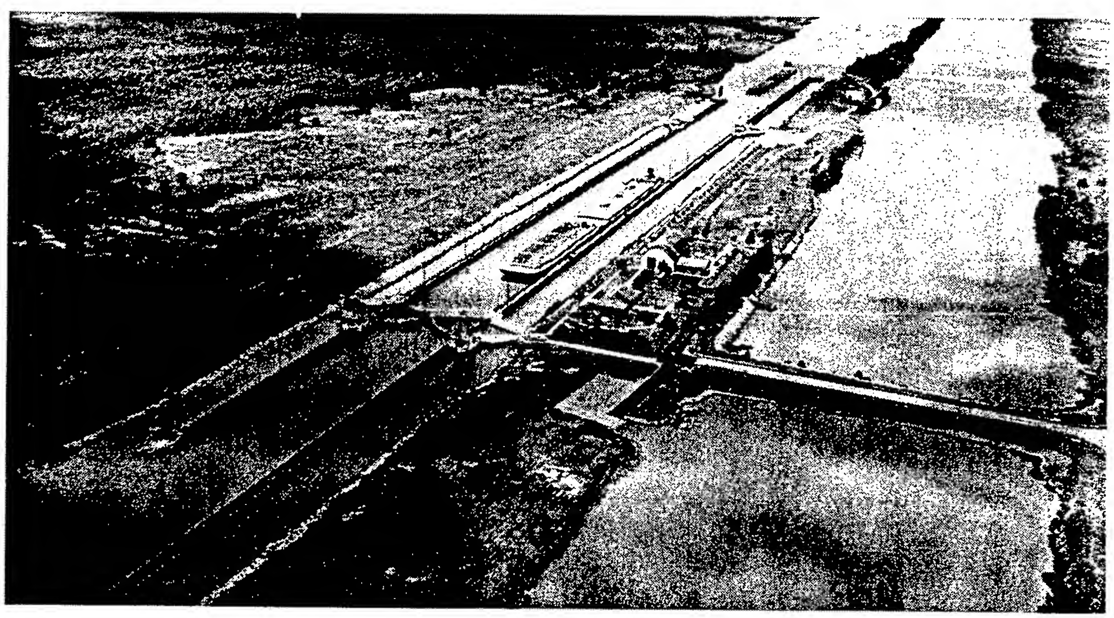


Figure 13. Aerial view of Leland-Bowman Lock.

The Leland-Bowman Lock is 110 ft wide, 1200 ft long, and about 16 ft deep. In 1998, the traffic at the lock consisted of more than 11,079 lockages for a total over 37.6 million tons of cargo. The purpose of this project is to provide a navigation channel from the Gulf Intracoastal Waterway at mile 161.2 west of Harvey Lock to the 12-foot depth contour in the Gulf of Mexico near Freshwater Bayou.

Hydraulic motors drive the sector gates on the lock. There are no valves at this lock as chamber level is adjusted by slightly opening the sector gates and allowing water to flow in to or out of the chamber. The lock will experience five feet of differential between headwater and tailwater only in the most extreme of situations. The usual lift is between one and two feet.

The lock has four control houses each equipped with a pushbutton control console that sends signals directly to the PLC system. The upstream control houses are numbered 1 and 2, and the downstream control houses are numbered 3 and 4. Control of the entire lock is possible from control booths 1 and 3 (the land wall of the lock chamber). Control booths 2 and 4 are capable of controlling the gates on their end of the lock (i.e., control booth 2 can control gates 1 and 2).

The lock has been operating with Allen Bradley PLC controls since 1996.

Table 90 describes the PLC.

Table 90. General PLC comments on Leland-Bowman Lock.

Subject	Comments
Input	Limit switches
Output	Gate-motor drivers
Manufacturer	Allen Bradley
Processor	PLC-5/40
Network Design	The network is now fully fiber optic.
System Design	The system allows for troubleshooting from a remote location.
PLC Programming Software	Allen Bradley 6200 Series

Additional comments about the PLC:

- The Allen Bradley system has been in place and virtually problem free since 1996
- It is programmed to run the gates only, but has the capacity to do more
- Most spare parts are in stock or reasonably attainable
- The tech support has been excellent
- The diagnostics of the system have become invaluable
- The use of fiber optics has eliminated problems with lightning strikes
- At the time of the visit, the local contractor from Rockwell Automation performed all PLC programming. The software itself works well and is easy to use.

Table 91 describes the OI.

Table 91. General OI comments on Leland-Bowman Lock.

Subject	Comments
Type	Pushbutton control panel
Manufacturer	N/A
PC Components	N/A
Monitor	N/A
Design	A refurbishing was done on the original control panel so the pushbuttons energize PLC inputs. The PLC is therefore "invisible" to the operators.
OI Software	N/A

Additional comments about the OI:

None

Table 92 describes the water level indicator.

Table 92. General water level indicator comments on Leland-Bowman Lock.

Subject	Comments
Type	Tile gauge on chamber walls
Manufacturer	N/A
Body Material	N/A
Electronics	N/A
Reliability	It is as dependable as the operator's eyes.
Accuracy	It is as accurate as the operator's eyes.

Additional comment about the water level indicator:

At the time of the visit, plans were being made to introduce increment encoders for water level indication in hopes of providing continual and comparably accurate (comparable to the operator's judgment) readings.

Table 93 describes the gate position indicator.

Table 93. General gate position indicator comments on Leland-Bowman Lock.

Subject	Comments
Type	Traveling nut limit switch
Manufacturer	Westinghouse
Body Material	No comments provided
Electronics	N/A
Reliability	When it is properly set, it is very reliable
Accuracy	N/A

Additional comments about the sector gate position indicator:

- When the lock is busy, the traveling nut limit switch must be reset once every two weeks
- It takes six months to replace parts for the traveling nut
- This device will be replaced by an encoder that will count the number of gear teeth passing by during lock gate operation. It was noted that counting shaft rotations introduces a chance for mechanical failure and erroneous position indication data
- Gate position throughout its path of motion is not monitored. The only indications of gate position are fully recessed and fully closed.

Table 94 describes the gate overtravel indicator.

Table 94. General gate overtravel indicator comments on Leland-Bowman Lock.

Subject	Comments
Type	Traveling nut limit switch
Manufacturer	Westinghouse
Body Material	No comments provided
Electronics	N/A
Reliability	When it is properly set, it is very reliable
Accuracy	N/A

Additional comment about the gate overtravel indicator:

Once the traveling nut has gone the full length of its calibrated path, a rocker-arm limit switch is triggered that initiates the shut down of the motor.

Table 95 describes the change-of-gate-speed indicator.

Table 95. General change-of-gate-speed indicator comments on Leland-Bowman Lock.

Subject	Comments
Type	Lever-arm limit switch along path of traveling nut
Manufacturer	Allen-Bradley
Body Material	No comments provided
Electronics	No comments provided
Reliability	Not very reliable
Accuracy	N/A

Additional comments about the change-of-gate-speed indicator:

- These limit switches have been a source of problems, but the PLC software enables good troubleshooting
- The seals leak and freeze up at times
- Every 2 – 4 years they have to be changed out at a cost of $100 each.

Calcasieu Lock

Lake Charles, LA, 16 March 1999
Lockmaster — Kevin Galley (337) 477-1482
Engineer Staff POC — Mike Park (504) 862-2302

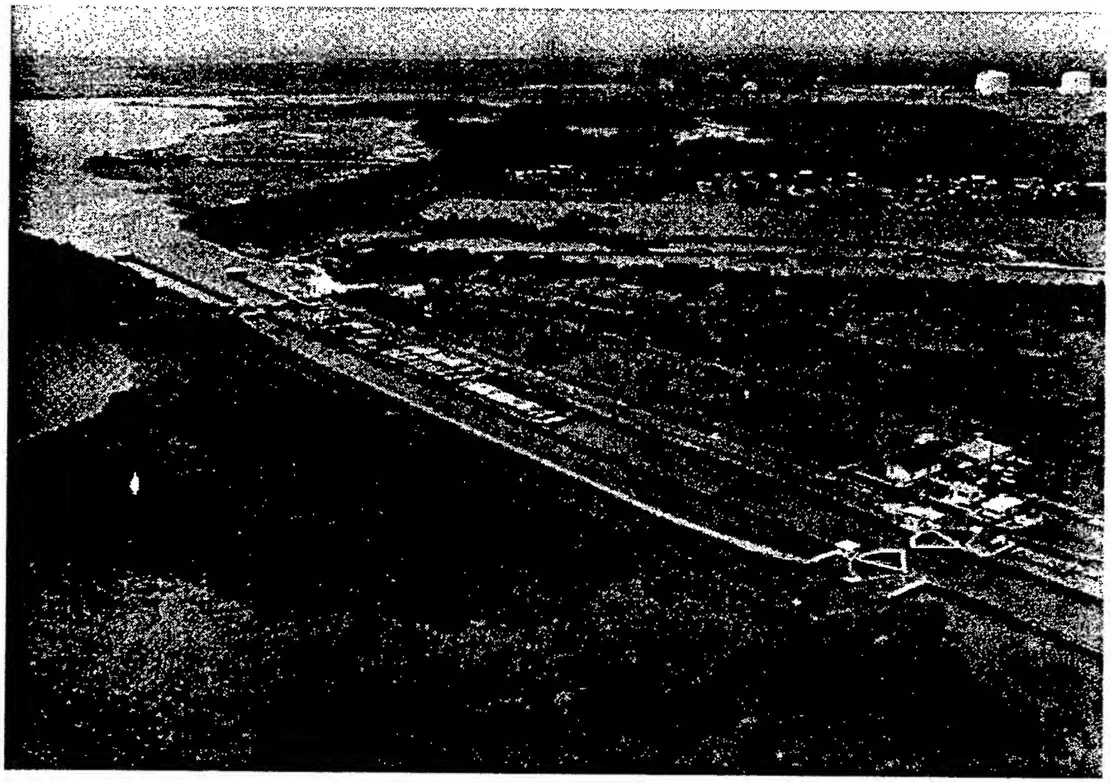


Figure 14. Aerial view of Calcasieu Lock.

The Calcasieu Lock is a 75 ft wide x 1200 ft long lock with a sill depth of about 16 ft. In 1998, the traffic at the lock consisted of 11892 lockages for a total over 37.3 million tons of cargo. The purpose of this project is to prevent salt-water intrusion of the upper area of the Gulf. Hydraulic motors drive the sector gates on the lock. There are no valves at this lock as chamber level is adjusted by slightly opening the sector gates and allowing water to flow in to or out of the chamber. There really is no lift at the lock. The pool level changes with tide differential, normally up to 4 ft.

The lock has four control houses each equipped with a pushbutton control console that sends signals directly to the PLC system. The upstream control houses are labeled A and B, and the downstream control houses are labeled C and D. Control of the entire lock is possible from control booths A and C (the land wall of the lock chamber). Control booths B and D are capable of controlling the gates on their end of the lock (i.e. control booth B can control gates A and B).

The lock has been operating with its current PLC controls since 1995. In the event that the PLC crashes, there is a hardwired backup control system in place.

Table 96 describes the PLC.

Table 96. General PLC comments on Calcasieu Lock.

Subject	Comments
Input	Limit switches
Output	Gate motor drivers
Manufacturer	Allen Bradley Model 1771 ABS Series D
Processor	PLC-5/40
Network Design	No comments provided
System Design	No comments provided
PLC Programming Software	Allen Bradley 6200 Series

Additional comments about the PLC:

- The local contractor handles all programming and system upgrades
- The system is programmed such that an operator has control of only one set of gates at a time.

Table 97 describes the OI.

Table 97. General OI comments on Calcasieu Lock.

Subject	Comments
Type	Pushbutton control panel
Manufacturer	N/A
PC Components	N/A
Monitor	N/A
Design	No comments provided
OI Software	N/A

Additional comment about the OI:

The original OI was refitted and retained due to operator familiarity.

Table 98 describes the water level indicator.

Table 98. General water level indicator comments on Calcasieu Lock.

Subject	Comments
Type	Tile gauge on chamber walls
Manufacturer	N/A
Body Material	N/A
Electronics	N/A
Reliability	It is as reliable as the operator's eyes
Accuracy	It is as accurate as the operator's judgment

Additional comments about the water level indicator:

None

Table 99 describes the gate position indicator.

Table 99. General gate position indicator comments on Calcasieu Lock.

Subject	Comments
Type	Cam and bull gear
Manufacturer	No comments
Body Material	No comments
Electronics	No comments
Reliability	It is reliable
Accuracy	It is accurate

Additional comments about the sector gate position indicator:

None

Table 100 describes the gate overtravel indicator.

Table 100. General gate overtravel indicator comments on Calcasieu Lock.

Subject	Comments
Type	Proximity switch
Manufacturer	Allen Bradley 871TM
Body Material	No comments provided
Electronics	No comments provided
Reliability	It is been reliable so far
Accuracy	It is accurate

Additional comments about the gate overtravel indicator:

- The Allen Bradley 871L proximity switches that were being used at the time of the visit had proven to be apparently susceptible to moisture and frequent failure
- These switches were being replaced by Allen Bradley 871TM switches in hopes that their material would eliminate faults caused by moisture
- Since the switch was made to Allen Bradley 871TM proximity switches, the situation has improved.

Table 101 describes the change-of-gate-speed indicator.

Table 101. General change-of-gate-speed indicator comments on Calcasieu Lock.

Subject	Comments
Type	Cam limit switch
Manufacturer	No comments
Body Material	No comments
Electronics	No comments
Reliability	It is reliable
Accuracy	It is accurate

Additional comments about the change-of-gate-speed indicator:

None

Portland District Locks (CENWP)

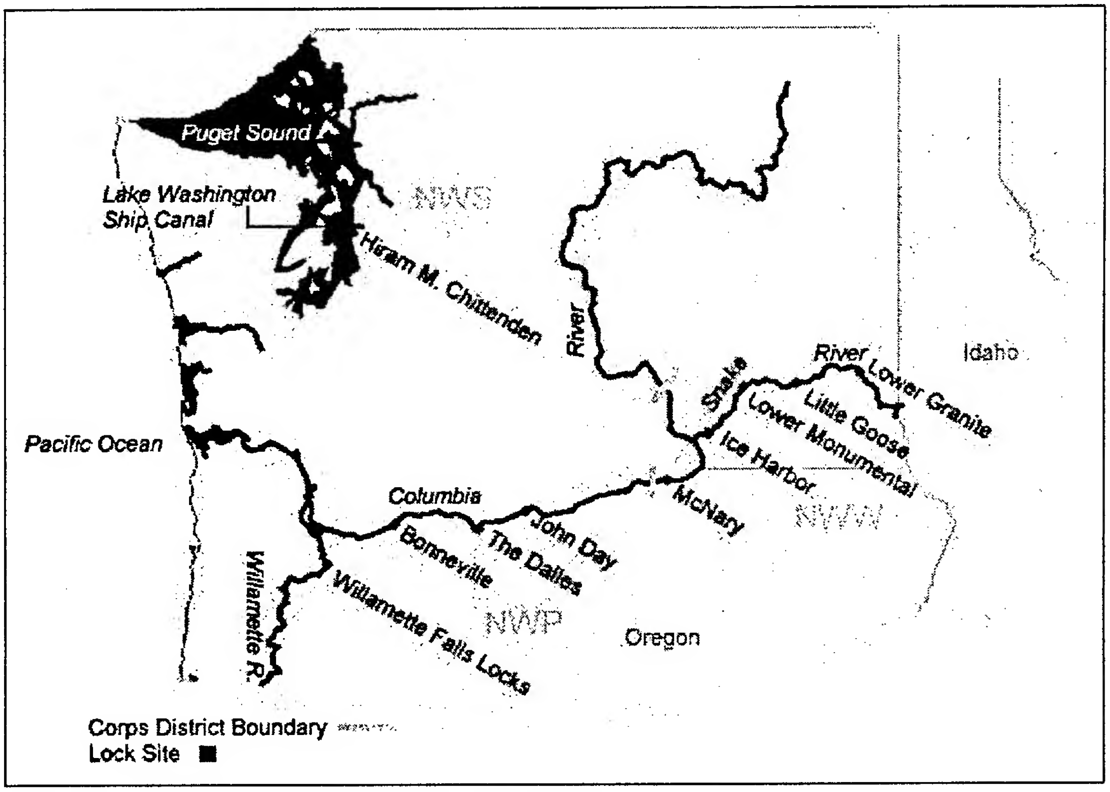


Figure 15. Location of Portland District Lock visited.

The Portland District investigates, plans, designs, constructs, operates, and maintains environmentally sound flood control, navigation and hydroelectric projects within the nearly 97,000 square miles of land and water in Oregon and southwest Washington that comprise it. The district operates navigation locks

on the 465-mile Columbia-Snake Inland Waterway and dredges that help maintain 720 miles of Federal navigation channel and harbors. Thirty million tons of cargo pass through Portland District ports and locks each year.

Bonneville Lock and Dam is included in this study.

Bonneville Lock and Dam

Bonneville, OR, 1 March 1999
Chief of Operations — Darrell Hunt (541) 374-4567
Electrician — Mark Smith (541) 374-4561

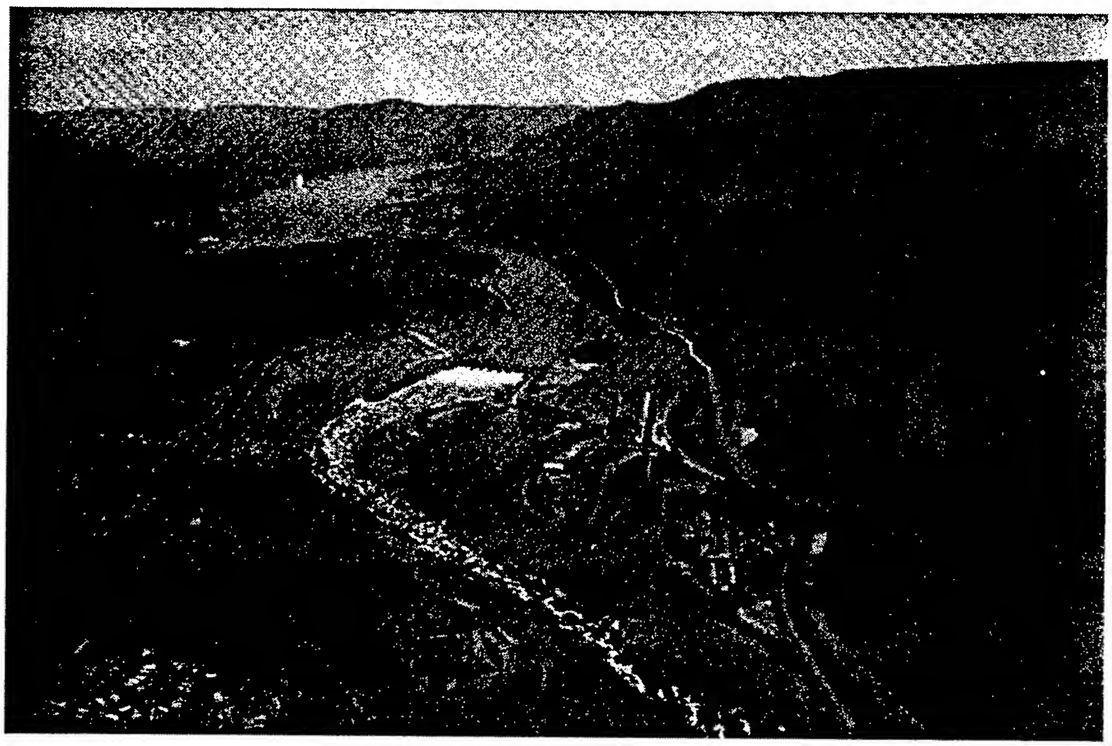


Figure 16. Aerial view of Bonneville Lock and Dam.

The Bonneville Lock and Dam is located in Cascade Locks, Oregon, on the Columbia River. The lock chamber is 675 ft long X 86 ft wide, with a maximum lift of 70 ft. It was commissioned in 1993, and replaced the old lock that had been operating since 1938. PLCs have been used at this lock since 1993. In 1998, the traffic at the lock consisted of 3243 lockages for a total nearly 10.8 million tons of cargo.

There are lock control stations located at both upstream and downstream ends of the lock. Complete control of the lock can be achieved at the downstream control station; i.e., at this control station, both upstream and downstream gates and

valves, horns, and traffic signals can be operated. Only the upstream gates, valves, and other upstream components can be operated from the upstream end. Also, there is a swing bridge at the downstream end, which can be operated only from the downstream end. The swing bridge must be operated in order to allow vessels to enter and exit the downstream end.

Each lock control station has a control panel for the lock with a schematic of the lock layout pictured on the panel; the switches for various components are positioned along the schematic in such a way as to reflect the approximate position of the components that are being controlled. In addition, a computer monitor on the right hand side provides a graphical display of the lock, along with the status of the lock gates, valves; and the headwater, tailwater, and chamber water levels. The swing bridge is operated from a separate console in the downstream control room.

There is a CCTV camera system, which consists of 11 cameras strategically positioned at each end, and along the middle of the lock chamber, and 4 monitors, which provide the operators with the ability to view the vessels and lock chamber from several different orientations. The lockage control sequence is not completely automatic, but instead consists of initiating separate commands for the individual components (e.g., gates and valves, etc.) via switches on the panel.

Table 102 describes the PLC.

Table 102. General PLC comments on Bonneville Lock.

Subject	Comments
Input	Limit switches, pool level indicator
Output	Gate motor drivers, traffic signals, valve motor drivers, boat calls, greasing machinery controls
Manufacturer	Square D
Processor	Square D SY/MAX 400
Network Design	Have SYNET LAN and can program from the lockmaster's office
System Design	No comments
PLC Programming Software	Square D

Additional comments about the PLC:

- Battery failure was noticed after two years, so batteries are changed once a year
- The Square D system allows for this battery change to be done without taking the system offline
- The system uses DOS programming downloaded from a PC to the PLC processor.

Table 103 describes the OI.

Table 103. General OI comments on Bonneville Lock.

Subject	Comments
Type	Pushbutton control panel
Manufacturer	N/A
PC Components	N/A
Monitor	N/A
Design	N/A
OI Software	N/A

Additional comments about the OI:

None

Table 104 describes the water level indicator.

Table 104. General water level indicator comments on Bonneville Lock.

Subject	Comments
Type	Pressure transducer
Manufacturer	Delta Controls 550 two-wire transmitter
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about the water level indicator:

- The pressure transducer with the bubbler systems was previously used, but it was affected by changes in barometric pressure
- The pressure transducer's readings are used in the PLC programming as part of the safety interlock system.

Table 105 describes the gate position indicator.

Table 105. General gate position indicator comments on Bonneville Lock.

Subject	Comments
Type	Rotary position transmitter
Manufacturer	Astrosystems, Inc. DuraPot HDC1000
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about the miter gate position indicator:

None

Table 106 describes the change-of-gate-speed indicator.

Table 106. General change-of-gate-speed indicator comments on Bonneville Lock.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Allen Bradley Limit Switches: Manuf. #803-A44
Body Material	No comments
Electronics	No comments
Reliability	It is reliable enough
Accuracy	It is accurate enough

Additional comments about the change-of-gate-speed indicator:

None

Table 107 describes the valve position indicator.

Table 107. General valve position indicator comments on Bonneville Lock.

Subject	Comments
Type	Rotary position transmitter
Manufacturer	Celesco Model PT9420-0200-111-110
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about the valve position indicator:

None

Table 108 describes the valve overtravel indicator.

Table 108. General valve overtravel indicator comments on Bonneville Lock.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Allen Bradley Limit Switch: Manuf. #802T-ATP
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about the valve overtravel indicator:

None

Table 109 describes the mitered/open indicator.

Table 109. General mitered/open indicator comments on Bonneville Lock.

Subject	Comments
Type	Lever arm limit switch
Manufacturer	Allen Bradley Limit Switches: Manuf. #802M-AMY5 Series B
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very accurate

Additional comments about mitered/open indicator:

None

Table 110 describes the CCTV system.

Table 110. General CCTV system comments on Bonneville Lock.

Subject	Comments
Purpose	Monitoring of lock traffic and facility grounds
Manufacturer	Burle
Camera	Burle TC652
Monitor	Burle TC1910
Design	No comments

Additional comment about CCTV systems:

Precipitation during periods of high winds has been suggested as a possible cause of camera damage due to moisture accumulation in the cameras.

St. Paul District Locks (CEMVP)

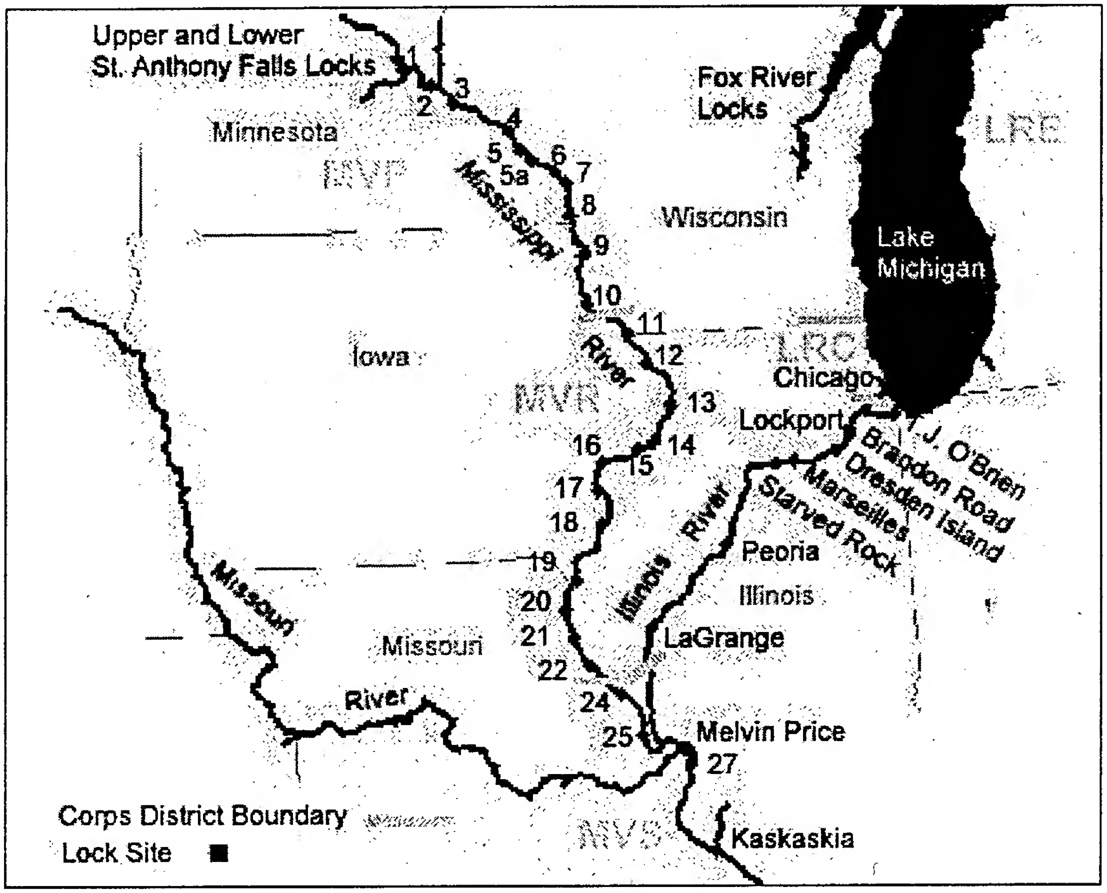


Figure 17. Location of St. Paul District Lock visited.

Lock 1

St. Paul, MN, 2 June 1999
Lockmaster — James Ryan (612) 724-2971
Maintenance Specialist — Duane Putz (612) 724-2971
Engineer Staff POC — Dave Valen (651) 290-5532

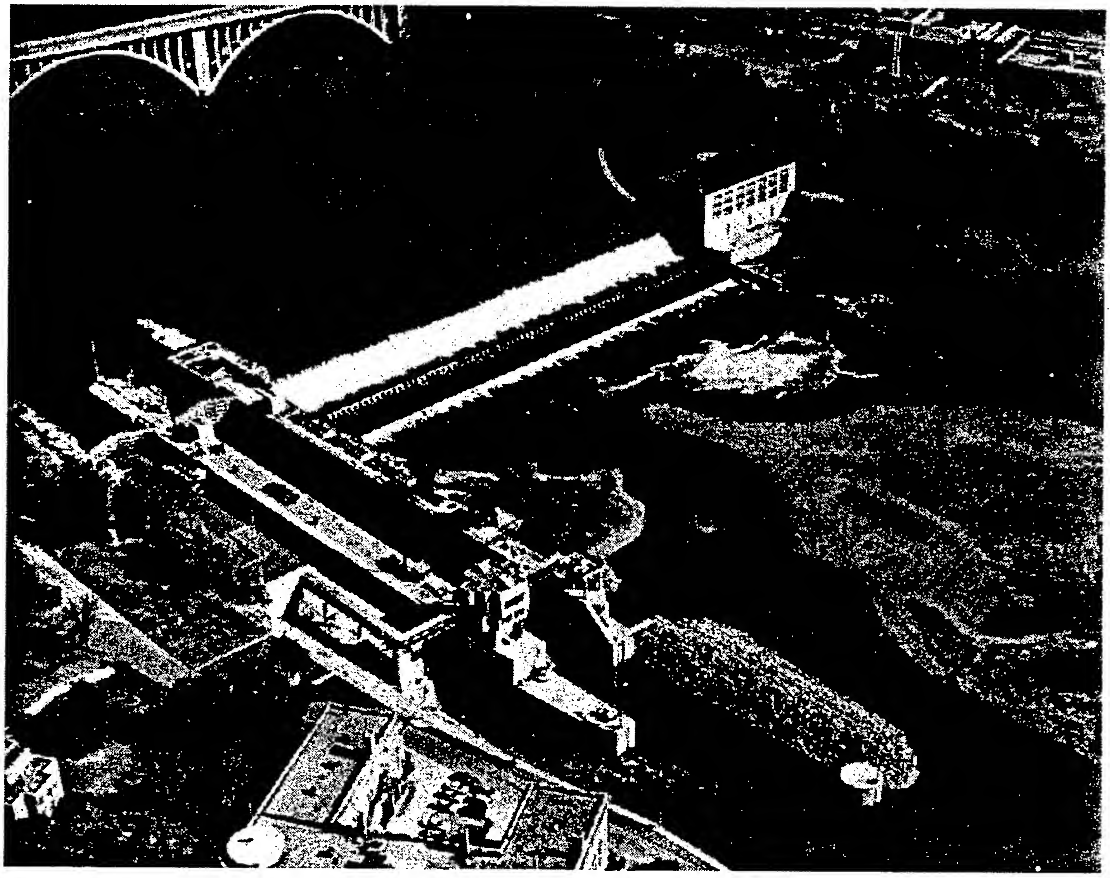


Figure 18. Aerial view of Lock 1.

Lock 1 is made up of two parallel 56 ft wide X 400 ft long chambers. There is a pair of miter gates at each end of each lock chamber. Hydraulic units drive the gates. The lock uses reverse tainter gates to control flow through its valves. These gates are driven by electric motors. The chamber is 50 ft deep and the lock usually operates under a 38 ft lift. In 1998, the traffic at the lock consisted of 3719 lockages for a total of nearly 2 million tons of cargo. It is important to note that Lock 1 is seasonally operational. It shuts down when the river freezes.

There are five control houses at the lock; one in the central tower that rests between the locks, two control houses on the land wall of the lock, and two control houses on the river wall of the lock. Each control house is equipped with a push-button control console that sends signals directly to the PLC system.

Each lock control station has a control panel for the lock with a schematic of the lock layout pictured on the panel; the switches for various components are positioned along the schematic in such a way as to reflect the approximate position of the components that are being controlled. The land lock can be totally controlled from the tower and land wall control houses. The river lock can be controlled from the river wall control houses. In the event that the PLC system fails, there

is manual backup in place for full lock operation. The lock has been operating with its current PLC controls for the past three years.

Table 111 describes the PLC.

Table 111. General PLC comments on Lock 1.

Subject	Comments
Input	Limit switches, position transmitters, pressure transducers
Output	Miter gate hydraulic motor drivers, valve motor drivers, lighting control
Manufacturer	Square D
Processor	SY/MAX Square D 600
Network Design	No comments provided
System Design	No comments
PLC Programming Software	Square D SY/Mate Plus

Additional comments about the PLC:

- It's easy to troubleshoot limit switch faults via the programming software
- The fiber optic lines were glued into their termination points upon initial installation. These glued fiber optic connections tended to crack up on the ends. The electrical maintenance staff got some fiber optic jumpers.
- PLC switches came on the first of two contracts for the lock's rehabilitation
- Hydraulic pressure units (HPU), valves, and mechanics came on the second of the two contracts
- The PLC system has battery backup to protect memory in the case of a power outage
- The lock has hardwired manual control for a backup in case the PLC fails
- The original Modicon 584 PLC system (which was susceptible to problems related to temperature) was replaced in 1994 with a Square D SY/MAX system
- The timing of valve opening is programmed through the PLC for various craft types to minimize turbulence in the chamber.

Table 112 describes the OI.

Table 112. General OI comments on Lock 1.

Subject	Comments
Type	Pushbutton control panel
Manufacturer	N/A
PC Components	N/A
Monitor	N/A
Design	Designed by Microswitch
OI Software	N/A

Additional comments about the OI:

None

Table 113 describes the water level indicator.

Table 113. General water level indicator comments on Lock 1.

Subject	Comments
Type	Pressure Transmitter
Manufacturer	Ametek Model 575
Body Material	No comments
Electronics	No comments
Reliability	Appears to be OK
Accuracy	It is very accurate

Additional comments about the water level indicator:

- Ametek has great technical support
- Druck Pressure Transducers were previously used at this lock, but problems were encountered with warranty, customer service, and repair costs. The Druck Pressure transducers were replaced with Ametek pressure transducers.
- The water level indicator is not included in lock automation programming (i.e., neither gate nor valve operation is automatically initiated based on water level measurements).

Table 114 describes the gate position indicator.

Table 114. General gate position indicator comments on Lock 1.

Subject	Comments
Type	Custom built steel rod and cable attached to hydraulic cylinder on miter gate and lever arm limit switches
Manufacturer	Telemecanique XSE-C1071301 lever arm limit switches
Body Material	No comments
Electronics	No comments
Reliability	Has been very reliable
Accuracy	Has been very accurate

Additional comments about the miter gate position indicator:

None

Table 115 describes the gate overtravel indicator.

Table 115. General gate overtravel indicator comments on Lock 1.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Telemecanique XSE-C1071301 lever arm limit switches
Body Material	No comments provided
Electronics	No comments
Reliability	The Telemecanique switches are far more reliable than their Microswitch predecessors
Accuracy	The switches are very accurate

Additional comment about the gate overtravel indicator:

They made sure to acquire switches intended for outside use.

Table 116 describes the change-of-gate-speed indicator.

Table 116. General change-of-gate-speed indicator comments.

Subject	Comments
Type	Custom built steel rod and cable attached to hydraulic cylinder on miter gate with lever arm limit switches
Manufacturer	Telemecanique XSE-C1071301 lever arm limit switches
Body Material	No comments
Electronics	No comments
Reliability	Has been very reliable
Accuracy	Has been very accurate

Additional comments about the change-of-gate-speed indicator:

None

Table 117 describes the valve position indicator.

Table 117. General valve position indicator comments on Lock 1.

Subject	Comments
Type	Potentiometer to resistance transducer to analog board to bar graph meter
Manufacturer	Parts from several manufacturers have been fitted to serve this task
Body Material	No comments
Electronics	No comments
Reliability	The mechanism is reliable
Accuracy	The mechanism is accurate

Additional comments about the valve position indicator:

None

Table 118 describes the valve overtravel indicator.

Table 118. General valve overtravel indicator comments on Lock 1.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Telemecanique XSE-C1071301 lever arm limit switches
Body Material	No comments
Electronics	No comments
Reliability	The devices are reliable
Accuracy	The devices are accurate

Additional comments about the valve overtravel indicator:

None

Table 119 describes the mitered/open indicator.

Table 119. General mitered/open indicator comments on Lock 1.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Telemecanique XSE-C107130
Body Material	No comments
Electronics	No comments
Reliability	They are reliable
Accuracy	They are accurate

Additional comments about the mitered/open indicator:

None

Huntington District Locks (CELRH)

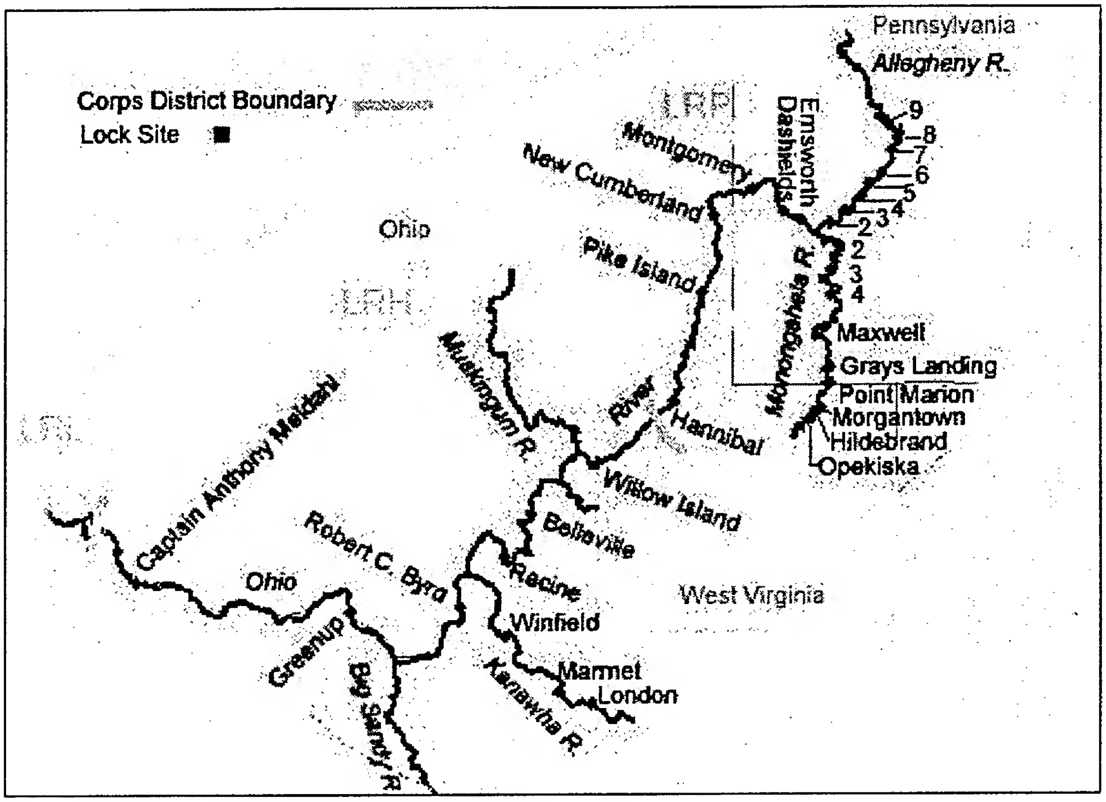


Figure 19. Location of Huntington District Lock visited.

The Huntington District is responsible for a geographic area in the Appalachian hills and mountains of southern and central West Virginia, eastern Kentucky, western Virginia, and northwestern North Carolina and to the rolling plains of southeastern and central Ohio. The district has developed the navigation infrastructure on the middle Ohio River and on the Kanawha River in West Virginia.

Winfield Lock and Dam

Midway, WV, 4 June 1999
Lockmaster —Terry Whitley (301) 486-2501
Engineer Staff POC — Brian Porter (304) 529-5618

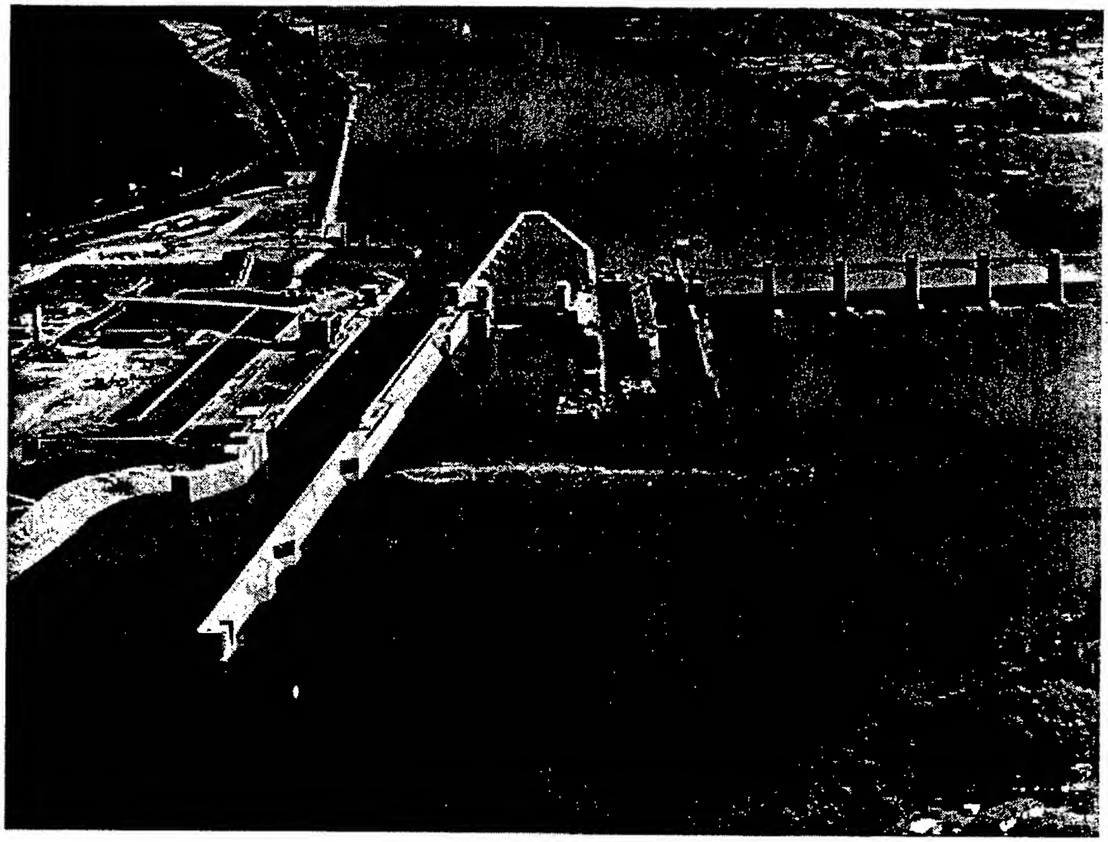


Figure 20. Aerial view of Winfield Lock and Dam.

The Winfield Lock and Dam is located on the Kanawha River 31.1 miles above the mouth of the river at Winfield, WV. The main lock at the site is 110 ft wide X 800 ft long with miter gates at each end. Hydraulic units that are PLC-controlled drive the miter gates, valves, and the large tainter gate on the dam. The roller gates on the dam are currently driven by electric motors and are not controlled by the PLC system.

Normal upper pool elevation 566.0 ft above sea level, upper pool length 36.7 miles to Marmet Dam, normal upper pool surface area 3100 acres, normal lower pool elevation 538.0 ft above sea level (upper pool of Gallipolis Dam), and normal lift 28.0 ft. Last year, 4050 barges used the lock to transport more than 21 million tons of cargo.

Control of the lock is managed by a central control tower that is equipped with a software-based operator interface. There are backup control stations on the lock walls with hardwired controls to enable full lock operation in the event of a PLC failure. CCTV cameras are used for security and assisting the lock operator in seeing what is going on at the lock.

The PLC system came as part of the rehabilitation of lock equipment in 1998.

Table 120 describes the PLC.

Table 120. General PLC comments on Winfield Lock.

Subject	Comments
Input	Position transmitter, limit switches
Output	Gate-motor driver, valve-motor driver, bubbler solenoid driver
Manufacturer	Square D
Processor	SY/MAX Model 444 SCP-444
Network Design	Operator Interface is connected to PLC through ACCESS 40000 interface
System Design	No comments provided
PLC Programming Software	Square D

Additional comments about the PLC:

- All communication is carried over fiber optic lines except that within and from the maintenance building
- There was some indication that some of the Square D components would not be supported in years to come
- Allen Bradley has been very dependable and has a very high market share
- For future remote control, there's a network module to the processors in the new dam gate and old gate control house
- The PLC can only be programmed via downloading the program from a PC or laptop
- Programming changes can not be made via the OI
- Both online and offline programming are available
- The PLC processor for the old dam must be programmed separately from the central processor that controls the miter gates and the new dam
- There are two control stations in place with hardwired manual controls to serve as backup in case the PLC system fails
- The PLC system designers chose not to enable remote dial-up programming or lock operation.

Table 121 describes the OI.

Table 121. General OI comments on Winfield Lock.

Subject	Comments
Type	PC/GUI
Manufacturer	IBM
PC Components	Various industry leaders
Monitor	NEC multisync XE21 (JC-2131VMA)
Design	No comments provided
OI Software	Interact 4.0 by CTC Operators love the OI

Additional comments about the OI:

- The DOS version of the software is very reliable
- The GUI-driven control system is basically a DOS application
- The OI software supports trending.

Table 122 describes the water level indicator.

Table 122. General water level indicator comments on Winfield Lock.

Subject	Comments
Type	Pressure transmitter
Manufacturer	Druck PTX 161D
Body Material	No comments provided
Electronics	No comments provided
Reliability	They have to regularly recalibrate it
Accuracy	Once the calibration is correct, the device is very accurate

Additional comments about the water level indicator:

- The pressure transducer is generally used for overfill/over empty monitoring
- The pressure transducer must be regularly recalibrated.

Table 123 describes the gate position indicator.

Table 123. General gate position indicator comments on Winfield Lock.

Subject	Comments
Type	Rotating shaft position indicator
Manufacturer	Astrosystems, Inc. Durapot HDC-24CRB
Body Material	No comments provided
Electronics	No comments provided
Reliability	It is reliable
Accuracy	It is very accurate

Additional comments about the miter gate position indicator:

- A DYMEC modem handles all sensor communications over fiber optic lines
- The signal from the device would oscillate, so a current isolator was installed to compensate for the problem
- With the current isolator in place, the readings from the device are dependable.

Table 124 describes the gate overtravel indicator.

Table 124. General gate overtravel indicator comments on Winfield Lock.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Cutler Hammer E50AR16P with KL220 rod
Body Material	No comments provided
Electronics	No comments provided
Reliability	It is reliable
Accuracy	It is accurate

Additional comments about the gate overtravel indicator:

None

Table 125 describes the change-of-gate-speed indicator.

Table 125. General change-of-gate-speed indicator comments on Winfield Lock.

Subject	Comments
Type	Two belts (one hooked to the gate and the other to a transducer) indicate how far along in the path the gate is and what speed the hydraulic ram should be operating at
Manufacturer	No comments
Body Material	No comments
Electronics	No comments
Reliability	Very reliable
Accuracy	Very reliable

Additional comment about the change-of-gate-speed indicator:

This system can be calibrated and programmed through the PLC.

Table 126 describes the valve position indicator.

Table 126. General valve position indicator comments on Winfield Lock.

Subject	Comments
Type	Rotating shaft position indicator
Manufacturer	Astrosystems, Inc. Durapot HDC-24CRB
Body Material	No comments provided
Electronics	The signal from the device would oscillate, so they had to add a current isolator (i.e., a rectifier).
Reliability	With the current isolator in place, the readings from the device are dependable
Accuracy	It is very accurate

Additional comments about the valve position indicator:

None

Table 127 describes the valve overtravel indicator.

Table 127. General valve overtravel indicator comments on Winfield Lock.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Cutler Hammer E50AR16P with KL220 rod
Body Material	No comments provided
Electronics	No comments provided
Reliability	It is reliable
Accuracy	It is accurate

Additional comments about the valve overtravel indicator:

None

Table 128 describes the mitered/open indicator.

Table 128. General mitered/open indicator comments on Winfield Lock.

Subject	Comments
Type	Magnetic proximity switches
Manufacturer	General Equipment Mfg. Co. GO switches 11-1241-G3 with AMC5 magnet
Body Material	No comments
Electronics	No comments
Reliability	It is reliable
Accuracy	It is accurate

Additional comments about the mitered/open indicator:

None

Table 129 describes the CCTV system.

Table 129. General CCTV system comments on Winfield Lock.

Subject	Comments
Purpose	Lock chamber and water discharge area monitoring
Camera	Burle TC351A
Camera Housing	Burle TC9340A (best investigator's guess)
Monitor	Burle TC1917 (obsolete model with no specifications information available)
Design	The cameras could have been positioned for better view of critical areas within the lock chamber

Additional comments about the CCTV system:

None

Rock Island District Locks (CEMVR)

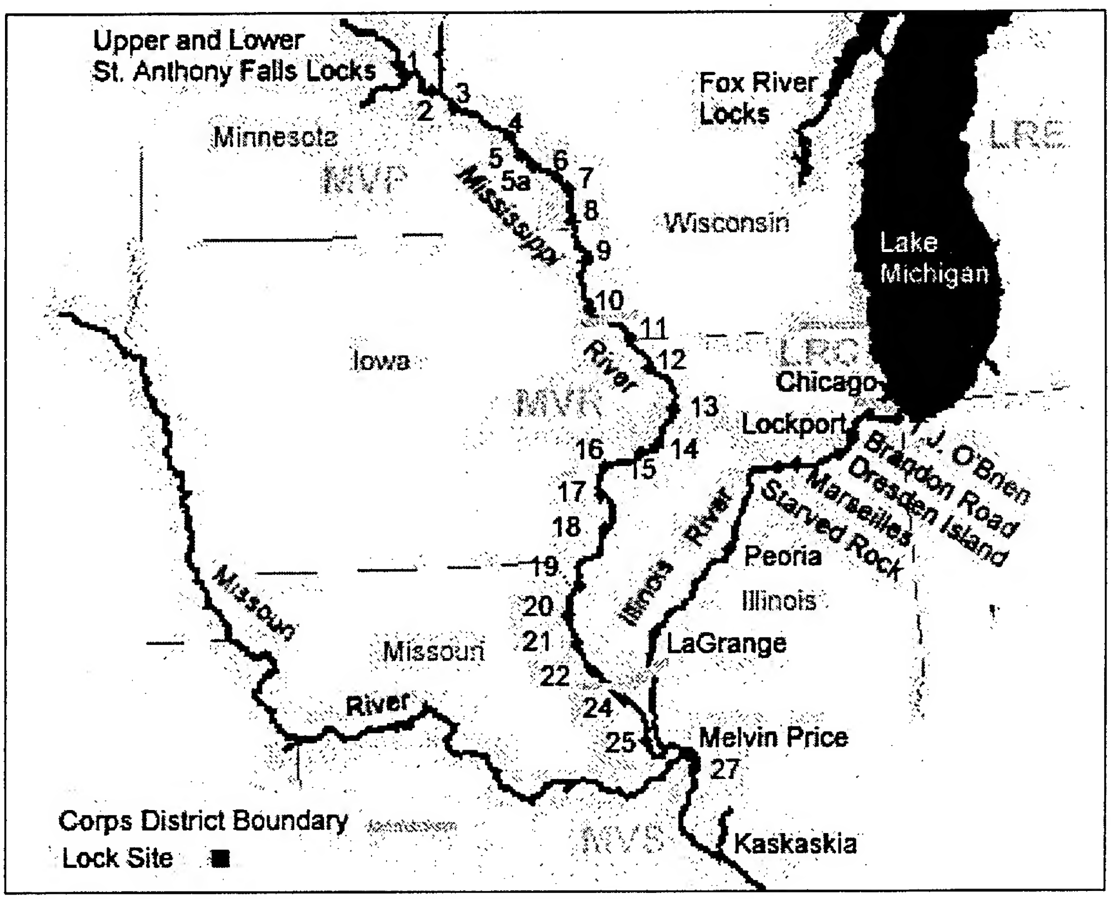


Figure 21. Location of Rock Island District Lock visited.

Rock Island District covers more than 78,000 square miles of land and includes 314 miles of the Mississippi River from Guttenberg, Iowa, to Saverton, Missouri, and 268 miles of the Illinois Waterway from Lake Street in downtown Chicago to the LaGrange Lock and Dam, southwest of Beardstown, Illinois.

It is primarily a civil works district administering Federal water resource development programs in large portions of Iowa and Illinois and smaller portions of Wisconsin, Minnesota, and Missouri. Some of the water resource management tasks that the district undertakes include navigation, environmental preservation, flood control, and recreation.

Lockport Lock in this district is included in this study.

Lockport Lock

Lockport, IL, 16 June 1999
Lockmaster — Patrick Wharry (815) 838-0536
Electrician — Dan Hooks (815) 838-0536

The Lockport Lock and Dam is part of the Illinois Waterway, Illinois and Indiana 9 ft channel. Located at Lockport, Illinois, the facility is 110 ft wide X 600 ft long. The normal downstream pool elevation is 538 ft above sea level, and the normal upstream pool elevation is 575 ft above sea level. At its upstream end the lock has two lift gates; one is used for normal service but the other is used only as an emergency lift gate. At its downstream end the lock chamber has a pair of miter gates. The lift gate has several redundant interlocks programmed into the PLC system to ensure safety and proper operations. The gates and valves at the lock are driven by electric motors. In 1998, the traffic at the lock consisted of 3316 lockages for 17.1 million tons of cargo.

At each end of the lock there are two local control rooms — one each on the river wall side and the land wall side — and either one can control the lock equipment at its respective end. Each control room is equipped with a pushbutton console that sends signals directly to the PLC system. Each lock control station has a control panel for the lock with a schematic of the lock layout pictured on the panel; the switches for various components are positioned along the schematic in such a way as to reflect the approximate position of the components that are being controlled.

Table 130 describes the PLC.

Table 130. General PLC comments on Lockport Lock.

Subject	Comments
Input	Gate limit switches, valve limit switches
Output	Gate motor drivers, valve motor drivers
Manufacturer	Allen Bradley
Processor	PLC-3 It is a 2nd generation PLC. It gets the job done, but needs to be upgraded
Network Design	No comments provided
System Design	No comments provided
PLC Programming Software	Allen Bradley AI Series by ICOM

Additional comments about the PLC:

- There is no central control (i.e., there are local control stations at the upstream and downstream ends of the lock).

- The safety interlocks of the lock are programmed into the PLC ladder, but that can be bypassed using manual keys in the control stations
- The system uses shielded twisted pairs for all communications between I/O points on the Allen Bradley data highway communications loop
- Documentation of wiring terminations is imperative
- Allen Bradley Dataliner outputs sensor status data continuously to a screen. This is a reliable diagnostic tool, but it generates substantial RF noise that interferes with hand-held radios
- The system was upgraded in two separate rehabilitation projects, so there is some inconsistency due to the two different contractors. Major documentation updates have been performed by maintenance personnel to clarify the design
- All communications are carried on the Allen Bradley "Blue Hose" which is made of copper twisted pairs. There has been no problem with lightning strikes
- The contractor programs all PLC logic
- A SWAN 486/33 PC holds the programming software and the ladder logic for troubleshooting and upgrading
- The programming software is great
- The addition of a cross reference table at the end of the ladder logic printouts showing every point that each point in the ladder affects has proven invaluable for troubleshooting.

Table 131 describes the OI.

Table 131. General OI comments on Lockport Lock.

Subject	Comments
Type	Pushbutton control panel
Manufacturer	No comments provided
PC Components	N/A
Monitor	N/A
Design	No comments provided
OI Software	The OI at this lock is the old "dead man switches" control panel

Additional comments about the OI:

None

Table 132 describes the water level indicator.

Table 132. General water level indicator comments on Lockport Lock.

Subject	Comments
Type	Watermarks on chamber walls and miter gates
Manufacturer	N/A
Body Material	No comments
Electronics	N/A
Reliability	It is as reliable as the operator's eyes
Accuracy	It is as accurate as the operator's judgment

Additional comments about the water level indicator:

- There was an Electromate Corporation 10FW3I air pressure system used for water level indication. It was such a high maintenance item that its use was abandoned within its first year. It was suggested that a capacitive water level indicator be used
- At the present time, water level is judged by the watermark on the wall of the lock chamber and by a bumper on the bottom of the miter gate.

Table 133 describes the gate position indicator.

Table 133. General gate position indicator comments on Lockport Lock (upstream).

Subject	Comments
Type	Optical encoder
Manufacturer	Allen Bradley Encoder Absolute Optical PLC-Type 845C-MJZ3DL3LN4
Body Material	No comments provided
Electronics	Provides a BCD output
Reliability	It is relatively reliable
Accuracy	It is accurate

Additional comments about drop (lift) gate position indicator:

- There is a drop (lift) gate at the upper end
- A resolver is more reliable, because the encoder has more moving parts which can lead to mechanical failure
- The interlocks for this gate were "over-engineered." As a result, the communications lines are a hybrid from two separate rehabs.

Table 134 describes the gate position indicator.

Table 134. General gate position indicator comments on Lockport Lock (downstream).

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Allen Bradley Bul. 802T-ATP
Body Material	No comments provided
Electronics	No comments provided
Reliability	The switches are very reliable now
Accuracy	No comments provided

Additional comments about the miter gate position indicator:

- Proximity switches were being considered at one time, but the mechanical switches have been so reliable that replacement did not appear to be warranted.
- There was a problem with lubrication at one time, but selection of a different lubricating spray has all but eliminated that. State Dri All Purpose Penetrant was used as the lubricating spray on the limit switches and the frequency of them wearing out has been reduced drastically.

Table 135 describes the gate overtravel indicator.

Table 135. General gate overtravel indicator comments on Lockport Lock.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Allen Bradley Bul. 802T-ATP
Body Material	No comments provided
Electronics	No comments provided
Reliability	The switches are very reliable now
Accuracy	No comments provided

Additional comments about the gate overtravel indicator:

- Proximity switches were being considered at one time, but the mechanical switches have been so reliable that it didn't seem worth it.
- There was a problem with lubrication at one time, but selection of a different lubricating spray has all but eliminated that. State Dri All Purpose Penetrant was used as the lubricating spray on the limit switches and the frequency of them wearing out has been reduced drastically.

Table 136 describes the change-of-gate-speed indicator.

Table 136. General change-of-gate-speed indicator comments on Lockport Lock.

Subject	Comments
Type	Optical encoder
Manufacturer	Allen Bradley Encoder Absolute Optical PLC-Type 845C-MJZ3DL3LN4
Body Material	No comments provided
Electronics	Provides a BCD output
Reliability	It is relatively reliable.
Accuracy	It is accurate

Additional comments about the change-of-gate-speed indicator:

A resolver is more reliable, because the encoder has more moving parts which can lead to mechanical failure.

Table 137 describes the valve position indicator.

Table 137. General valve position indicator comments on Lockport Lock.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Allen Bradley Bul. 802T-ATP
Body Material	No comments provided
Electronics	No comments provided
Reliability	The switches are very reliable now
Accuracy	No comments provided

Additional comments about valve position indicator:

- Proximity switches were being considered at one time, but the mechanical switches have been so reliable that it did not seem worthwhile to make the change
- There was a problem with lubrication at one time, but selection of a different lubricating spray has all but eliminated that. State Dri All Purpose Penetrant was used as the lubricating spray on the limit switches and the frequency of them wearing out has been reduced drastically.

Table 138 describes the valve overtravel indicator.

Table 138. General valve overtravel indicator comments on Lockport Lock.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Allen Bradley Bul. 802T-ATP
Body Material	No comments provided
Electronics	No comments provided
Reliability	The switches are very reliable now
Accuracy	No comments provided

Additional comments about valve overtravel indicator:

- Proximity switches were being considered at one time, but the mechanical switches have been so reliable that it did not seem reasonable to make the change
- State Dri All Purpose Penetrant was used as the lubricating spray on the limit switches and the frequency of them wearing out has been reduced drastically.

Table 139 describes the mitered/open indicator.

Table 139. General mitered/open indicator comments on Lockport Lock.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Allen Bradley Bul. 802T-ATP
Body Material	No comments provided
Electronics	No comments provided
Reliability	The switches are very reliable now
Accuracy	No comments provided

Additional comments about the mitered/recessed indicator:

- Proximity switches were being considered at one time, but the mechanical switches have been so reliable that it did not appear worthwhile to make the change
- There was a problem with lubrication at one time, but selection of a different lubricating spray has all but eliminated that. State Dri All Purpose Penetrant was used as the lubricating spray on the limit switches and the frequency of them wearing out has been reduced drastically.

Jacksonville District Locks

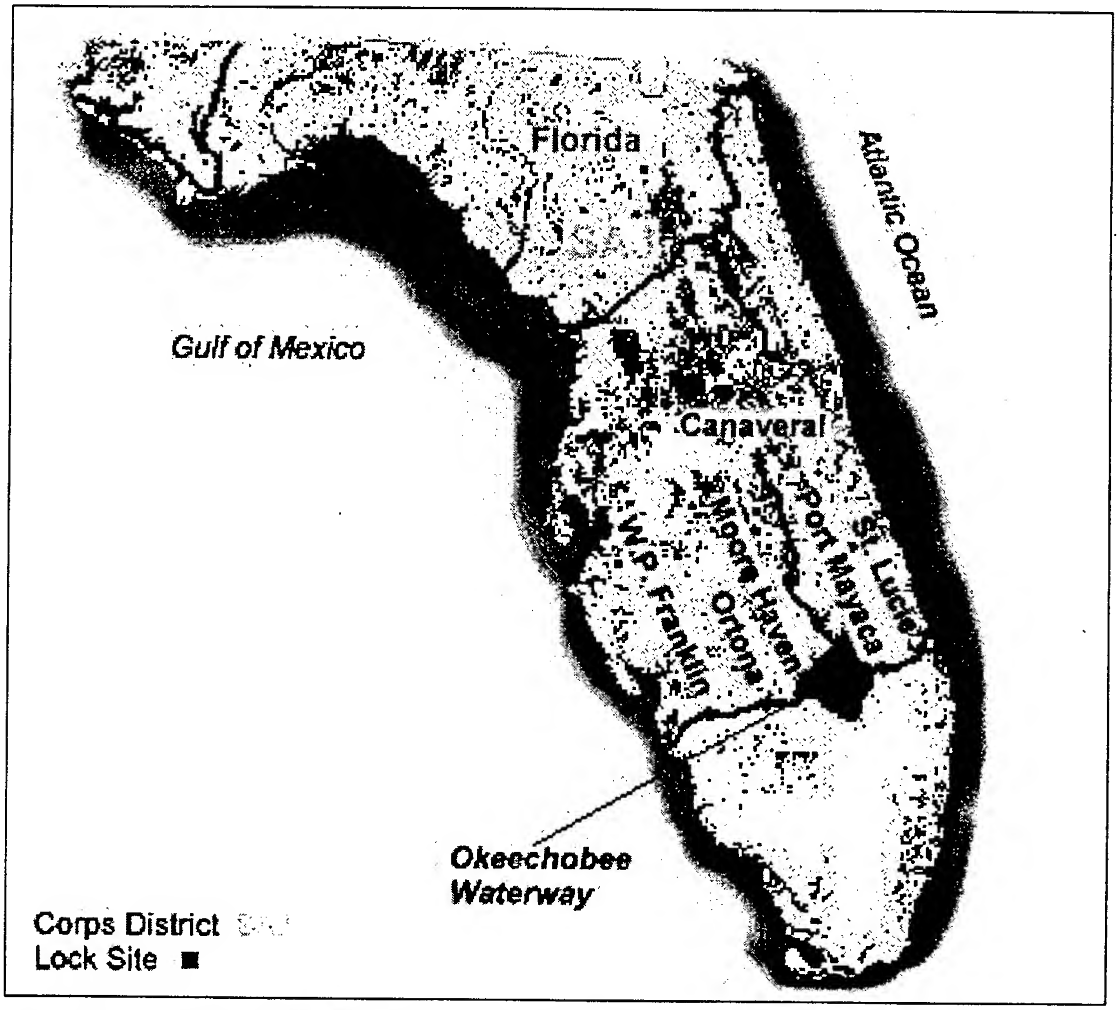


Figure 22. Location of Jacksonville District Lock visited.

The Jacksonville District is the second largest civil works district in the nation and maintains an extremely complex system of flood control works. Projects are often designed for multi-purpose uses, such as storage of water for municipal and industrial use, navigation, irrigation, development of hydroelectric power, conservation of fish and wildlife, and recreation. Flood protection is provided through aggressive floodplain management and by providing technical assistance to local governments.

The Port St. Lucie Lock, that is the first lock encountered on the Okeechobee Waterway when traveling from the Atlantic Ocean, is included in this study.

Port St. Lucie Lock

Stuart, FL, 19 February 1999
Regional Lockmaster — Billy Mason (407) 924-2858

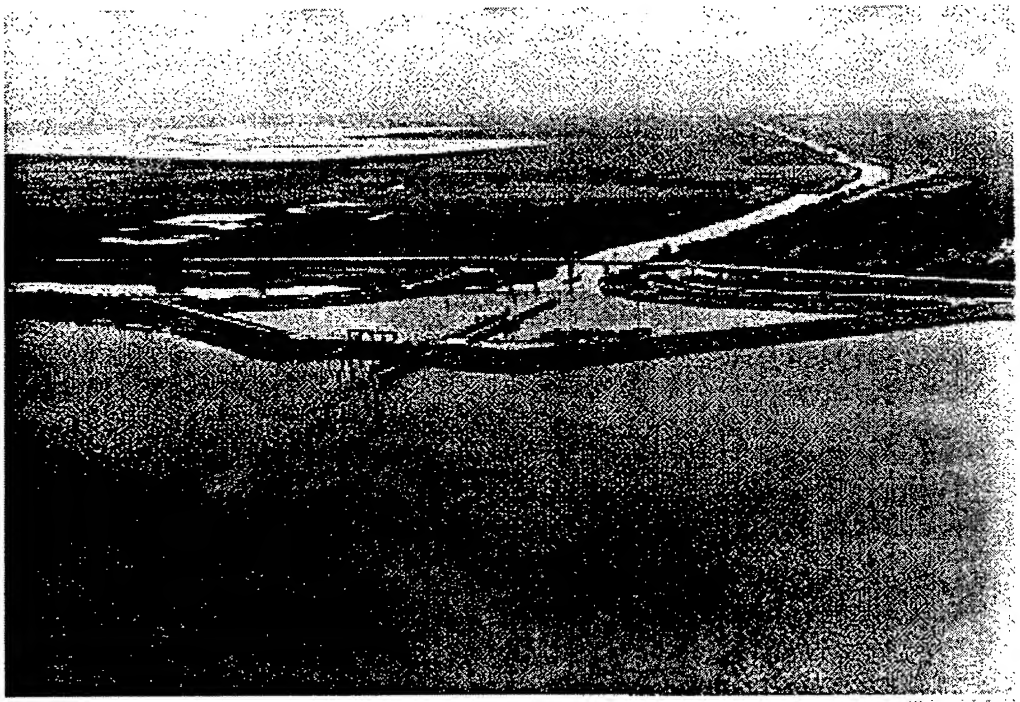


Figure 23. Aerial view of Port St. Lucie Lock.

Port St. Lucie Lock is located near Stuart, Florida (about 20 miles north of West Palm Beach) on the St. Lucie Canal, from which Lake Okeechobee empties into the Atlantic Ocean. It is mainly a lock for pleasure boats. The lock chamber is 250 ft long X 50 ft wide with a lift of 13 ft. Sector gates both allow boats into and out of locks and are used to fill and empty the locks. The sector gates are operated by variable frequency drive (VFD) motors. The lock has had PLC-based controls since 1982.

Originally, the PLC system was also used to control the filling and emptying rate of the lock chamber by automatically regulating the amount of opening of the sector gates. However, this system proved to be unreliable, and the filling /emptying rate is now operator-controlled by opening the sector gates a small amount based on operator experience.

From 1982 to 1991, there were some problems with support of equipment by contractors. The lock equipment is now serviced by the Clewiston Operations Office.

Table 140 describes the PLC.

Table 140. General PLC comments on Port St. Lucie Lock.

Subject	Comments
Input	Limit switches
Output	Traffic light drivers, gate motor drivers
Manufacturer	Allen Bradley
Processor	Allen Bradley PLC-2/30
Network Design	No comments
System Design	No comments
PLC Programming Software	Allen Bradley

Additional comments about the PLC:

- System maintenance has changed several times
- It was first installed in 1982; from 1982-1989, it was maintained by the contractor who installed it; from 1989-1991, it was maintained by low bidder (checked every 6 months); from 1991-present, it is maintained by Clewiston Operations Office
- Clewiston's electrician maintains the motors variable frequency drives
- Clewiston provides all technical support for the lock (the office is two hours away)
- The factory has been called 3 times since 1991
- Parts are getting harder to find for this old PLC system
- They have the programming box that came with the system, but no one knows how to use it
- The Clewiston Office uses a PC for programming the PLCs
- Port St. Lucie is the only lock in the region that Clewiston services.

Table 141 describes the OI.

Table 141. General OI comments on Port St. Lucie Lock.

Subject	Comments
Type	Pushbutton control panel
Manufacturer	No comments
PC Components	N/A
Monitor	N/A
Design	N/A
OI Software	N/A

Additional comments about the OI:

None

Table 142 describes the water level indicator.

Table 142. General water level indicator comments on Port St. Lucie Lock.

Subject	Comments
Type	Tile gauge on lock wall
Manufacturer	N/A
Body Material	N/A
Electronics	N/A
Reliability	As reliable as the operator's sight
Accuracy	As accurate as the operator's judgment

Additional comment about the water level indicator:

A bubbler water level indicator system was used at one time; however, it proved to be unreliable; and the usage of that system was abandoned.

Table 143 describes the gate position indicator.

Table 143. General gate position indicator comments on Port St. Lucie Lock.

Subject	Comments
Type	Rotary position transmitter
Manufacturer	Synchro-transmitter model 5T Henschel CORP
Body Material	No comments
Electronics	No comments
Reliability	It is reliable
Accuracy	It is accurate

Additional comments about the gate position indicator:

None

Table 144 describes the gate overtravel indicator.

Table 144. General gate overtravel indicator comments on Port St. Lucie Lock.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Allen Bradley 802MC mechanical limit switches
Body Material	No comments
Electronics	No comments
Reliability	It is reliable
Accuracy	It is accurate

Additional comments about the gate overtravel indicator:

None

Table 145 describes the change-of-gate-speed indicator:

Table 145. General change-of-gate-speed indicator comments on Port St. Lucie Lock.

Subject	Comments
Type	Lever-arm limit switch
Manufacturer	Allen Bradley 802MC mechanical limit switches
Body Material	No comments
Electronics	No comments
Reliability	No comments
Accuracy	No comments

Additional comments about the change-of-gate speed indicator:

None

Table 146 describes the CCTV system.

Table 146. General CCTV system comments on Port St. Lucie Lock.

Subject	Comments
Purpose	Monitoring of lock traffic and facility grounds
Manufacturer	Phillips
Camera	Phillips 1152/007
Monitor	Phillips VS82505T
Design	No comments

Additional comments about the CCTV system:

None

3 Conclusions

A survey of 15 Corps-operated lock sites (which includes 19 lock chambers) that use programmable logic controller (PLC) based automation revealed many significant differences in technology implementation. An evaluation matrix was developed for purposes of rating and comparing PLCs, sensors, switches, and CCTV cameras and monitors now operating in the field. This matrix and the evaluation procedure provide a valid system for rating and comparing lock control systems and associated components. The data collected from the 15 lock sites have been assembled into a database documenting the status of lock automation in Corps-operated locks. Site-specific automation design has been dictated to a large extent by differences in individual experience and preferences of engineers and lockmasters, in addition to considerations of lock traffic, physical dimensions, gate types, lift requirements, etc.

An economic analysis of lock automation alternatives conducted previously by Rock Island District was determined to be relevant to the current study and is incorporated into this report as Appendix A. The Rock Island District analysis determined that PLC-based lock automation systems could save 60 percent in construction costs and 30 percent in life-cycle costs compared to a standard hardwired relay-based system with no backup capability. The analysis provides important economic and operational perspectives that should be considered in conjunction with the findings of the lock evaluation conducted under this study.

The performance scores for the PLC-based control systems evaluated (Appendix B) were generally good to excellent at most sites visited, indicating that most lockmasters, electricians, and operators are generally satisfied with the PLC-based systems they use. PLCs have reduced the number of relays necessary for lock equipment operation. These systems have made it possible for the lock electrician to modify the lockage program in a matter of minutes and monitor the status of some equipment online in real time. The data processing capabilities of PLC-based automation also offer the potential for developing predictive maintenance applications.

In evaluating the operator interface (OI) used by various PLC-controlled systems, there was very little difference in the performance scores of pushbutton control panels versus the graphical user interface (GUI). From an operations perspective, neither type of OI appears to have an advantage over the other as

used in existing lock automation systems. However, GUI-based controls provide the potential to display more information about equipment status than pushbutton controls. As traffic increases at a particular lock facility and advances in automation are sought, the information display capabilities of a GUI would provide important new control and status-monitoring capabilities for lock personnel. Some of the electrical maintenance personnel interviewed in this study suggested that a GUI also would provide more flexibility for future augmentation of system capabilities, and that this benefit alone would help to justify the cost of retooling.

The interfacing of various sensors and equipment through the PLCs (for gate position, water level, degree of valve opening, etc.) has provided safety interlocks that prevent inappropriate operation of lock valves and gates, traffic signals, and horn. The use of fiber optics for lock automation communication lines in some of the systems studied has greatly reduced the amount of copper wiring needed between control stations and the motor control centers, and this provides an additional safety factor: decreased susceptibility of the system to lightning strikes. The use of CCTV systems further enhances operational safety by enabling lock operators to view a variety of locations within the lock from a single control station. The use of CCTV systems also provides the capability to enhance site security.

Draft specifications for lock automation equipment in the form of draft Corps of Engineer Guide Specifications (CEGS) were prepared. These draft CEGS (Appendix C) address specifications for procurement and installation of components for PLCs, control and instrumentation systems, and industrial personal computers and networks.

References

Bannister, Brandt D., Duncan Kwong, and Jeffery L. Nelson, "PLC Based Control System at the Bonneville Navigation Lock," Proceedings: U. S. Army Corps of Engineers Electrical /Mechanical Engineering Conference, June 1996.

Emmerling, Marvin M., "David D. Terry Lock and Dam Expert Spillway Gate Control System," Proceedings: U. S. Army Corps of Engineers Electrical /Mechanical Engineering Conference, June 1996.

Omega Engineering Inc., *Book 2 Purchasing Agents Edition: Pressure, Flow and Level, Data Acquisition, pH and Conductivity*, Vol. 29, 1995.

Porter, B. G., "Control System for Winfield Additional Lock and Gate Bay," Proceedings: U. S. Army Corps of Engineers Electrical /Mechanical Engineering Conference, June 1996.

Radtke, Bryan, and David Rodgers, "Alternatives Analysis for Lock Control Systems", U.S. Army Corps of Engineers, Rock Island District, December 1995.

U.S. Army Corps of Engineers, "Control Stations and Control Systems for Navigation Locks and Dams," Engineering Technical Letter No. 1110-2-553, Department of the Army, Washington, DC 20314-1000.

U. S. Army Corps of Engineers, "Gate Operating Equipment for Navigation Locks and Spillways," Draft Engineering Manual EM1110-2-2610, Department of the Army, Corps of Engineers, Washington, DC 20314-1000.

U.S. Army Corps of Engineers, St. Louis District-Engineering Division, *Melvin Price Locks and Dam Operations and Maintenance Manual*, First Edition; Chapter 2.2-2.3.

Appendix A: Alternatives Analysis for Lock Control Systems

Bryan Radtke and David Rodgers

US Army Corps of Engineers
Rock Island District
Clock Tower Building, ED-DG
P.O. Box 2004
Rock Island, Illinois 61204-2004

December 1995

List of Tables and Figures

Tables

Figures

INTRODUCTION

PURPOSE. This document presents four alternatives that could be installed for a navigation lock electrical control system.

POLICY. The major rehabilitation of Mississippi River Lock No. 14 included replacement and repair of electrical, mechanical, structural, and other site features. The major rehabilitation program is paraphrased as follows: "When significant impacts to users have occurred, or are about to occur, then service shall be restored through rehabilitation with an expected extended life of 25 years." The replacement of the navigation lock electrical system equipment includes power distribution, navigation lock controls, and navigation lock lighting which have a system design life of not less than 25 years. The concept of change is encouraged by both Engineer Manual (EM) 1110-2-2602 and general interest in potential improvements in navigation lock control systems. The DRAFT EM 1110-2-2602 included requirements that new navigation locks were required to use Programmable Logic Control (PLC) systems and rehabilitated navigation locks should consider this alternative for incorporation. The FINAL EM 1110-2-2602 changed the requirements regarding use of PLC systems and has removed all requirement to use PLC systems, but it still suggests that PLC systems be considered for use.

ANALYSIS CRITERIA. It is the navigation lock <u>control system</u> that is the focus of this alternatives analysis and all considerations for the other electrical systems are assumed to be unchanged between alternatives. Each of the alternatives analyzed herein are currently used at USACE navigation locks and Alternative 3 is based on a PLC system at Illinois Waterway Lockport Lock in the Rock Island District. Other districts that utilize PLC lock control systems have been contacted. Engineering division personnel from other districts reported some startup problems that they indicate could have been avoided with improved system design. This implies that use of conversation and experience in the design phase of the PLC controls system should be implemented.

The construction cost estimates were developed in part by using cost data from estimates completed for major rehabilitation at Mississippi River Lock No. 13 and PLC replacement at Mississippi River Lock No. 1. Other cost data was obtained from Means 1995 Electrical Cost Estimating Data and from an electrical equipment manufacturer. Support was provided by CENCR-ED-C for conversion adjustments to move present costs to the intended construction start year 1997. The engineering and design costs reflect the actual the negotiated A-E cost and estimated costs associated with a design change.

The reliability and maintenance costs were determined from industry experience as recorded by IEEE and electrical equipment manufacturers. The data obtained from IEEE was in terms of failure rates. The data obtained was the mean time between failures (MTBF). Probability and statistical analysis applied to the data determined the number of components that may fail over the system's life and subsequently the associated maintenance costs. Actual navigation lock equipment repair and replacement costs are not documented as separate events and are not available for analysis.

The construction cost, design cost, reliability, and maintenance costs were used to determine the life-cycle cost analysis. Support was provided by CENCR-PD-C for the implementing method and format for calculation of the life-cycle system cost for each alternative.

There are unique advantages and disadvantages with all purely hardwired systems as compared and contrasted to all purely PLC systems. The specific advantages and disadvantages unique to each alternative as it varies from the generalization is addressed under the respective alternative. A general comparison/contrast is documented on the following pages.

COMPARISON OF ADVANTAGES

BETWEEN

HARDWIRED SYSTEM AND PLC SYSTEMS

HARDWIRED LOCK CONTROL SYSTEM

ADVANTAGES:

- Maintenance familiarity.
- Most transient voltage tolerant.
- Replacement parts readily available and competitively priced.
- Experienced reliability.
- Existing design plans are mostly repetitive from previous rehabilitations, except add site specifics and lessons learned.

PROGRAMMABLE LOGIC CONTROLLER (PLC)

ADVANTAGES:

- Reduces the quantity of control cables.
- Eliminates all control relays, timers, and flashers.
- Reduces the size of ductbanks and cable congestion in manholes.
- Reduces quantity and size of control cables into main switchboard.
- Reduces quantity of auxiliary contacts on devices.
- Reduces quantity of terminal blocks, splices, and connections.
- Very adaptable.
- Monitoring of lock equipment available at any control station.
- Expansion of system (now or future) could monitor and report sensor failures.

COMPARISON OF DISADVANTAGES

BETWEEN

HARDWIRED SYSTEM AND PLC SYSTEMS

HARDWIRED LOCK CONTROL SYSTEM

DISADVANTAGES:

- Highest cost; greatest initial cost followed by greatest recurring costs for modifications and additions or changing function.
- Greatest use of space; greatest exposure to flood damage.
- Least flexible; modifications and additions or changing function have greatest limitations.
- Greatest time required for construction.

PROGRAMMABLE LOGIC CONTROLLER (PLC)

DISADVANTAGES:

- Electronic devices are more susceptible to power fluctuations and lightning, however, proven preventative measures would be incorporated to result in comparable susceptibility.
- Maintenance for equipment and programming changes requires higher skill level from maintenance personnel. Training is required.
- Need to keep replacement parts for components (i.e., Input/Output modules and all replaceable electronic logic boards).
- Technology is valid for approximately 25 years. Parts may be obsolete.

ALTERNATIVES ANALYSIS

ASSUMPTIONS. There are features and equipment for each alternative that can be changed to enhance the design and operation of the navigation lock electrical system. These features are common to each alternative and were ignored in the analysis. These items should be addressed during the design of locks. Each alternative should allow additional savings by changing these items and the amount of allowable change would be unique to the chosen alternative (i.e., PLC alternatives would allow size reduction of the switchboard, need for re-evaluation of the use of pistol-grip switches, use of a decoder instead of cam limit switches, etc.).

Only the control system of the navigation lock are addressed in this analysis. Power and lighting equipment is assumed to be the same for each alternative.

The main switchboard is assumed to remain centralized and of the same size for each alternative. The size and distributed locations should be reviewed during the design process. Control equipment, relays, and wiring within the switchboard was addressed in the analysis.

The control stands are assumed to remain the identical size and location. There are equal operator interfaces in each alternative except ALTERNATIVE 4 which would add operator pushbuttons for backup operation. Control operator interfaces (i.e., pistol-grip switches, pushbutton type, etc.) should be reviewed for enhancement during the design process.

The miter gate and tainter valve position sensors are assumed to remain the same for each alternative. Changes to these sensors are identical for each alternative and should be considered during the design process.

Alternative 1

DESCRIPTION. Hardwired Lock Control System. This system is similar to and based upon the lock control system installed at Mississippi River Lock No. 13. This system incorporates a control safety interlock that is hardwired between all of the equipment. This system has no backup capabilities. This alternative is the base design and the alternatives are essentially compared to it in the analysis.

FEATURES. Alternative 1 includes the installation and use of line voltage (120 volts) copper wires, relays, and timers to control the lock's miter gates, tainter

valves, control interlocks, traffic lights, horn, guidewall lights, and lock lights. This system can be viewed as the report base design and is similar to the locks previously renovated. An emergency stop would be incorporated. The operator interfaces would be similar to the control desk panel that was installed within the control stands at the previously rehabilitated locks (i.e., Lock 13). All miter gate and tainter valve control position sensors would be durable and suitable for the lock's environment.

ADVANTAGES. See the generalized Advantages for Hardwired control systems in the Introduction Section.

DISADVANTAGES. See the generalized Disadvantages for the Hardwired control systems in the Introduction Section.

RELIABILITY. This alternative contains a hardwired system with no backup capability. The downtime due to a system failure is dependent upon the lock electrician's ability to perform the repair and the availability of replacement parts. The lock electrician is highly familiar and skilled with the hardwired lock control system and replacement parts are normally available. Many spare parts are kept in inventory. The lock would be partially or totally inoperable, depending on which equipment fails (i.e., the inoperation of one tainter valve does not stop navigation) until the hardwired system is repaired. Downtime would be less than 4 hours on average, depending on the type of failure.

COST

Construction Cost: $689,261

Annual Maintenance Cost: $2,951

Life-Cycle Cost: $945,619

BLOCK DIAGRAM. See the block diagram for Alternative 1 in Figure A-1.

Alternative 2

DESCRIPTION. Programmable Logic Controller (PLC) Lock Control System. This system uses a single PLC and all associated equipment to control the lock functions with a control safety interlock system internal to the PLC software. This system has no backup capabilities.

FEATURES. Alternative 2 includes the installation and use of a PLC to control the lock's miter gates, tainter valves, control interlocks, traffic lights, horn, guidewall lights, and lock lights. An emergency stop would be incorporated. The PLC system would incorporate supplementary grounding, power transient suppressors, and fiber optic communication cable to suppress transients caused by lightning and unclean power. The operator interfaces would be similar to the control desk panel that was installed within the control stands at the previously rehabilitated locks (i.e., Lock 13). All miter gate and tainter valve control position sensors would be durable and suitable for the lock's environment.

ADVANTAGES. See the generalized Advantages for PLC control systems in the Introduction Section.

DISADVANTAGES. See the generalized disadvantages for PLC control systems in the introduction section and the alternative specific disadvantage below.

◊ No partial failure in the event the PLC system failed. Failure of lock operations would be total and downtime would be dependent upon the repair time of the PLC.

RELIABILITY. This alternative contains a PLC system with no backup capability. A system failure is dependent upon the lock electrician's ability to perform the repair or the response obtained from the manufacturer's repair service. Spare parts will be kept in inventory for all PLC components and are included in the annual maintenance cost. Until the PLC system is repaired, the lock would be inoperable. Downtime would be less than 4 hours on average, but could be as long as 8 hours depending on the type of failure.

COST

Construction Cost: $248,998

Annual Maintenance Cost: $5,879

Life-Cycle Cost: $610,946

BLOCK DIAGRAM. See the block diagram for Alternative 2 in Figure A-2.

Alternative 3

DESCRIPTION. Programmable Logic Controller (PLC) Lock Control System With Redundant PLC Central Processing Unit (CPU). This system uses two

CPU's and all associated equipment to control the lock functions where one of the CPU's is constantly on-line as backup to the main CPU. The control safety interlocks are internal to the PLC software and would be active on the backup CPU also. Failure of non-redundant remote input and output (I/O) peripheral equipment would cause failure of the PLC control system.

FEATURES. Alternative 3 includes the features of Alternative 2 and also incorporates the installation of a second (backup) PLC CPU that will operate simultaneously with the main PLC CPU. Normal features of Alternative 3 includes the installation and use of a PLC to control the lock's miter gates, tainter valves, control interlocks, traffic lights, horn, bubbler system, guidewall lights, and lock lights. An emergency stop would be incorporated. The PLC system would incorporate supplementary grounding, power transient suppressors, and fiber optic communication cable to suppress transients caused by lightning and unclean power. The operator interfaces would be similar to the control desk panel that was installed within the control stands at the previously rehabilitated locks (i.e., Lock 13). All miter gate and tainter valve control position sensors would be durable and suitable for the lock's environment. A backup PLC CPU would be designed to run simultaneously (known as hot backup) and would assume control from the main CPU if failure occurred in the main CPU. Remote I/O racks would NOT be redundant.

ADVANTAGES. See the generalized Advantages for PLC control systems in the Introduction Section and the alternative specific advantages below.

◊ There is full backup in the event the main PLC CPU failed.

◊ The remotely located Input/Output racks contain modular self-diagnostic equipment that can be repaired by the lock electrician (electrician must be provided with PLC training). Adequate spare parts for this equipment would be kept at the lock.

◊ Control safety interlocks are maintained on a backup system.

DISADVANTAGES. See the generalized Disadvantages for PLC control systems in the Introduction Section and the alternative specific disadvantages below.

◊ Downtime may occur if remotely located Input and Output modules or the remote sending/receiving units fail. Duration would depend on the lock electrician's ability to repair the failure with spare parts.

RELIABILITY. This alternative contains a PLC system with partial backup capability. A failure of the main CPU would cause no downtime. A system failure of remote equipment depends on the lock electrician's ability to perform the repair on remote I/O modules and equipment or the response obtained from the manufacturer's repair service. Spare parts will be kept in inventory for all PLC components and are included in the annual maintenance cost. Failure of the main CPU would cause no downtime and replacement would be done as soon as possible, but would not affect navigation. An I/O failure would cause the lock to be inoperable until the PLC remote I/O component is repaired and navigation would be affected. Downtime would be less than 4 hours on average, but also depends on the type of failure.

COST

Construction Cost: $262,144

Annual Maintenance Cost: $6,064

Life-Cycle Cost: $627,163

BLOCK DIAGRAM. See the block diagram for Alternative 3 in Figure A-3.

Alternative 4

DESCRIPTION. Programmable Logic Controller (PLC) Lock Control System With Partial Hardwire Backup Control. This system uses a single PLC and all associated equipment to control the lock functions with a control safety interlock system internal to the PLC software. In addition, the system uses auxiliary emergency backup control panels that are located at the upstream and downstream landwall control stands that will operate the upstream land and river wall and the downstream land and river wall equipment respectively. The control safety interlock is integral only to the PLC and will be inoperative on the backup system. Heightened operator awareness is required when operating on the backup system.

FEATURES. Alternative 4 includes the features of Alternative 2 and also incorporates the installation of a partial hardwire backup system that uses momentary pushbuttons and interposing relays to directly operate the critical lock equipment using the normal position sensors for position control. The backup system would essentially force the starters to energize to the requirements of sensors. Critical lock equipment would include miter gates, tainter valves, and traffic lights. Normal features of Alternative 4 includes the installation and use

of a PLC to control the lock's miter gates, tainter valves, control interlocks, traffic lights, horn, bubbler system, guidewall lights, and lock lights. An emergency stop would be incorporated. The PLC system would incorporate supplementary grounding, transient suppression, and fiber optic communication cable to suppress surges caused by lightning and unclean power. The operator interfaces would be similar to the control desk panel that was installed within the control stands at the previously rehabilitated locks (i.e., Lock 13). All miter gate and tainter valve control position sensors would be durable and suitable for the lock's environment. The upstream and downstream land wall control stands would contain emergency backup operator controls and interposing relays for the sensors to operate the land wall and river wall miter gates and tainter valves. The control interlocks would not be functional when using the hardwire backup system because the interlocks are incorporated in the PLC software only.

ADVANTAGES. See the generalized Advantages for PLC control systems in the Introduction Section and the alternative specific advantages below.

◊ There is full backup in the event the PLC system failed.

◊ The remotely located Input/Output racks contain modular self-diagnostic equipment that can be repaired by the lock electrician (provided with PLC training). Adequate spare parts for this equipment would be kept at the lock.

DISADVANTAGES. See the generalized Disadvantages for PLC control systems in the Introduction Section and the alternative specific disadvantages below.

◊ Backup system does not incorporate the interlocks. Heightened operator awareness is required when operating on backup.

◊ Short disruption of navigation may occur if remotely located Input and Output modules or the remote sending/receiving units fail. Duration would depend on the operator's switchover to the partial hardwire backup system. Timely repair would be preferable. The hardwire backup would keep the lock operable.

RELIABILITY. This alternative contains a PLC system with partial backup capability. Failure of the PLC would not result in any lock downtime. The partial hardwire backup will allow lock operations to continue.

COST

Construction Cost: $291,928

Annual Maintenance Cost: $6,832

Life-Cycle Cost: $667,751

BLOCK DIAGRAM. See the block diagram for Alternative 4 in Figure A-4.

SUMMARY

Alternatives Summary List

- Alternative 1 is a Hardwired Control System.
- Alternative 2 is a single PLC Control System.
- Alternative 3 is a PLC Control System with a Hot Backup CPU.
- Alternative 4 is a PLC Control System with a Partial Hardwired Backup System.

Table A-1 presents a cost summary of the four alternative lock control designs. Table A-2 presents a life cycle cost analysis for the four designs.

Table A-1. Cost Summary.

PROJECT: LOCK 14 CONTROL SYSTEM ALTERNATIVES ANALYSIS REPORT
SUBJECT: COST COMPARISON SUMMARY – CONSTRUCTION COST, ANNUAL MAINTENANCE COST AND LIFE-CYCLE COST

	ALTERNATIVE 1 (BASE DESIGN)	ALTERNATIVE 2	ALTERNATIVE 3	ALTERNATIVE 4
CONSTRUCTION COST	$689,261	$248,998	$262,144	$291,928
CONST. COST DIFFERENCE*	$0	$440,263	$427,117	$397,333
ANNUAL MAINTENANCE COST	$2,951	$5,879	$6,064	$6,832
ANN. MAINT. COST DIFFERENCE	$0	($2,928)	($3,113)	($3,881)
LIFE-CYCLE COST	$945,619	$610,946	$627,163	$667,751
LIFE-CYCLE COST DIFFERENCE*	$0	$334,673	$318,456	$277,868

* DIFFERENCE IS RESPECTIVE ALTERNATIVE COST LESS THE COST OF ALTERNATIVE 1. POSITIVE NUMBER INDICATES SAVINGS. NUMBERS IN PARENTHESIS ARE COSTS.

Table A-2. Life-cycle costs analysis for four alternative designs for lock control.

NCR-PD-C				Dec-95
LIFE-CYCLE COST ANALYSIS SPREADSHEET				
Programmable Logic Controller (PLC) Study for L/D 14.				
Cost Item	**ALTERNATIVE 1**	**ALTERNATIVE 2**	**ALTERNATIVE 3**	**ALTERNATIVE 4**
Design Cost	$157,400	$257,400	$257,400	$257,400
Construction Cost	$689,261	$248,998	$262,144	$291,928
No. of Construction Years	2	2	2	2
Annual Maintenance Cost	$2,951	$5,879	$6,064	$6,832
Periodic Replacement Costs:				
No major component replacements are scheduled during project life.				
Project Life	25	25	25	25
Federal Discount Rate	7.625%	7.625%	7.625%	7.625%
Cost Analysis:				
Capital Costs (Design & Const.)	$846,661	$506,398	$519,544	$549,328
Interest During Construction**	$66,421	$39,727	$40,758	$43,095
Discounted Annual Maint. Cost	$32,537	$64,821	$66,860	$75,328
Present Value of Total Lifecycle Costs	**$945,619**	**$610,946**	**$627,163**	**$667,751**

ALTERNATIVE 1: Existing Hardwired Control System (Similar to L/D 13).
ALTERNATIVE 2: PLC without backup system.
ALTERNATIVE 3: PLC with redundant on-line PLC CPU backup system.
ALTERNATIVE 4: PLC with partial hardwired backup system.

** Interest During Construction assumes 2-year construction period for all plans, with equal funds expenditures in each year (using mid-year expenditure/compounding convention).

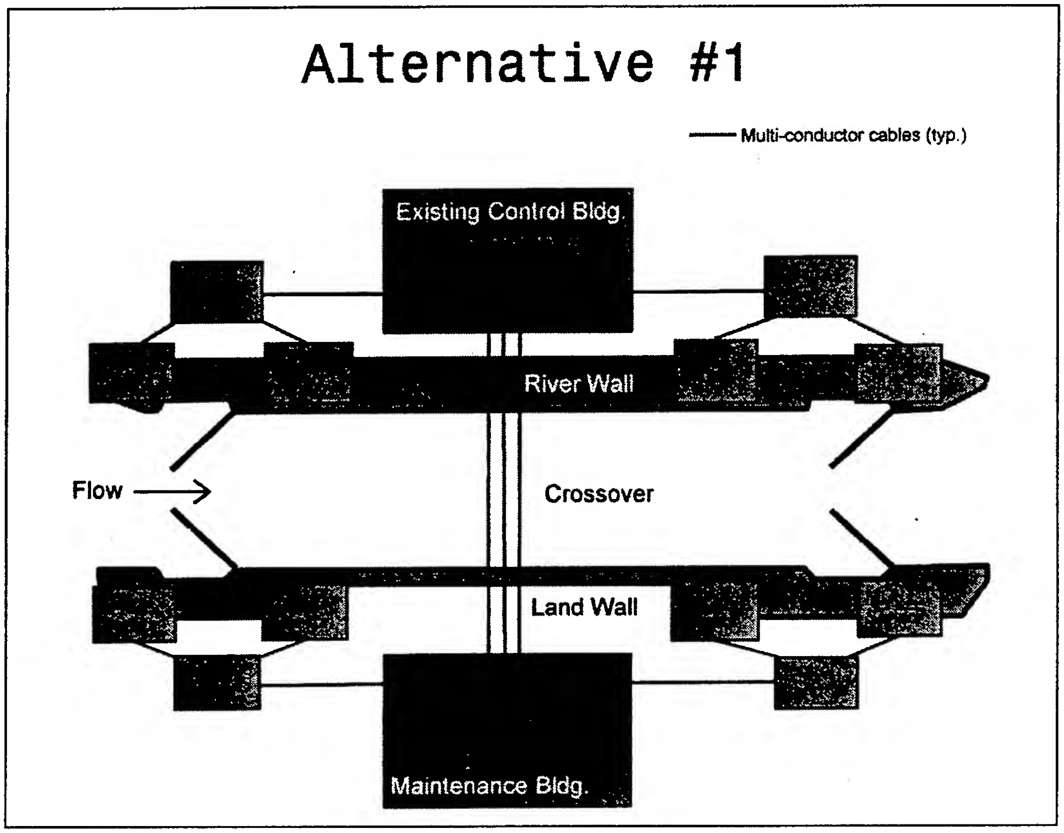


Figure A-1. Alternative 1 is a hardwired control system.

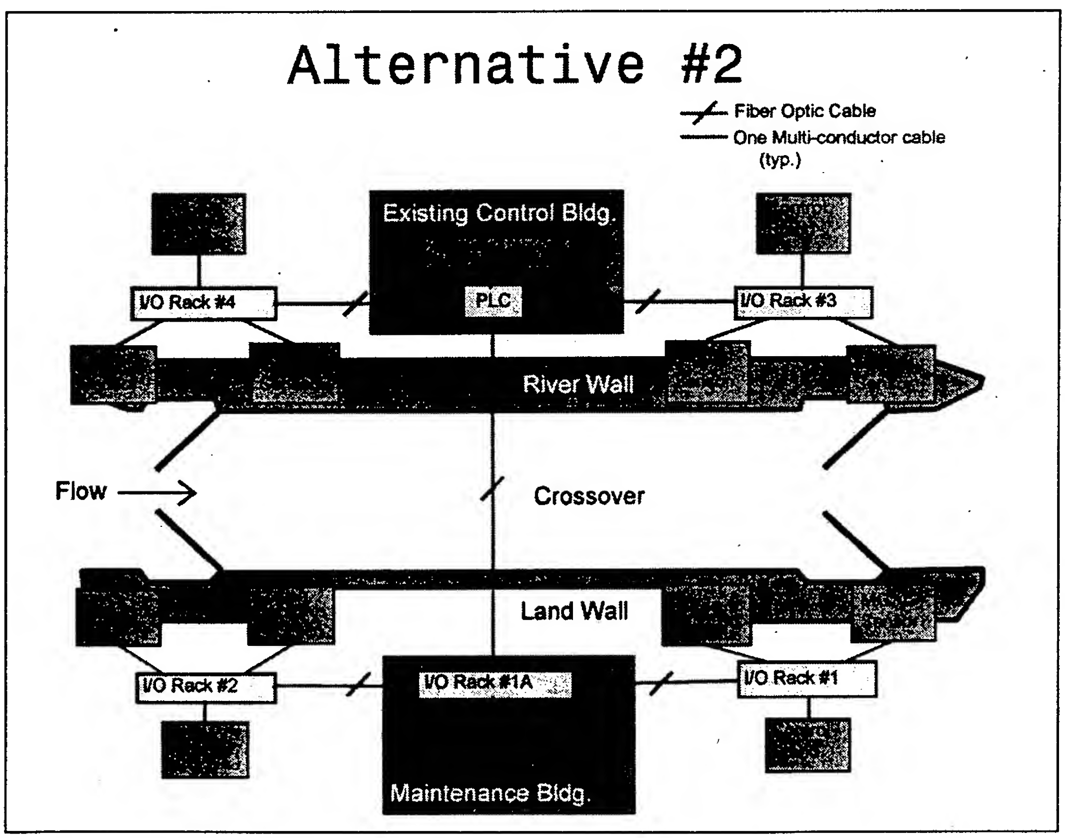


Figure A-2. Alternative 2 is a single PLC control system.

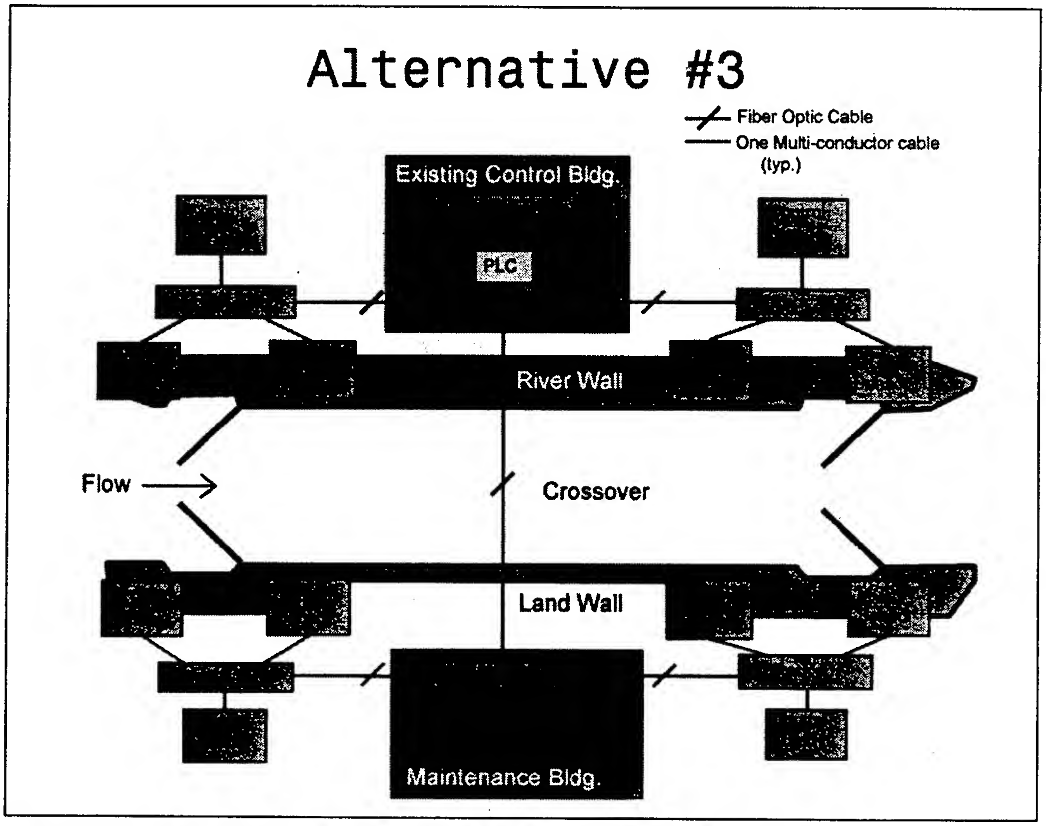


Figure A-3. Alternative 3 is a PLC control system with a hot backup CPU.

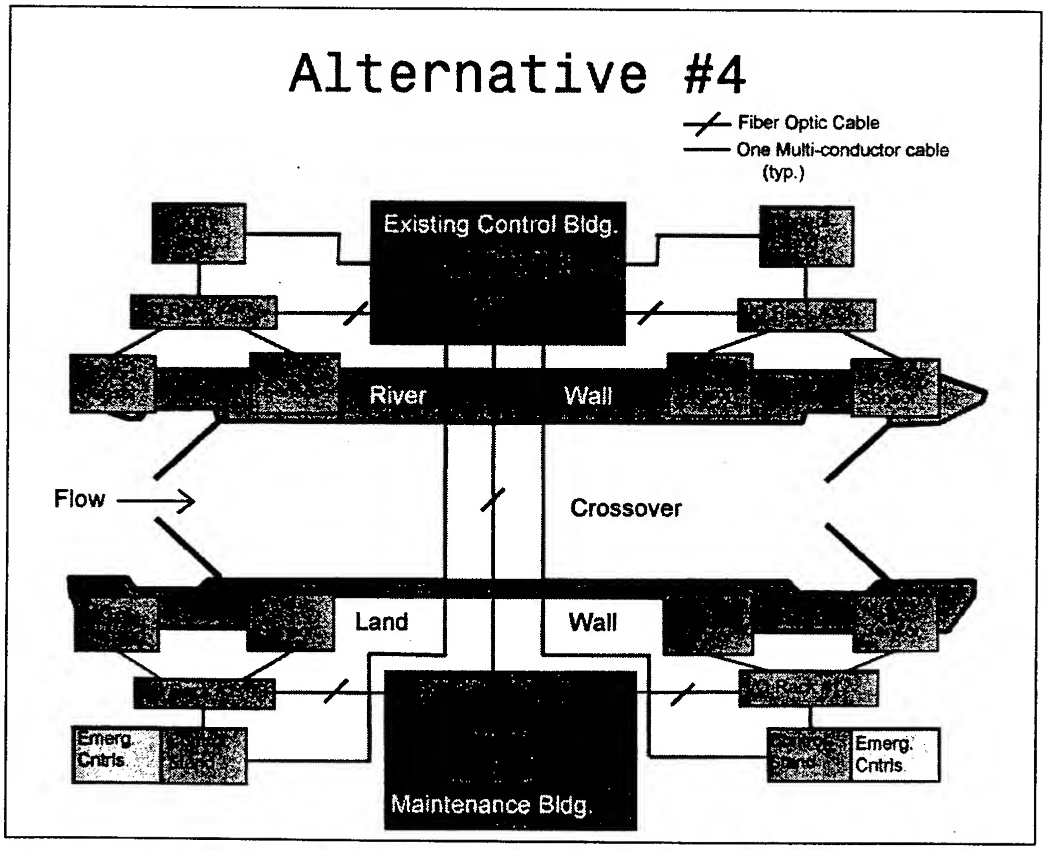


Figure A-4. Alternative 4 is a PLC control system with a partial hardwired backup system.

Appendix B: Lock Evaluation Forms

List of Figures and Tables

Figures

Tables

General

There are two types of evaluations: **specification** and **performance**. The specification evaluation form was developed with the hope of giving those systems with the highest quantity of available options the highest score. **Neither of the manufacturers included in this study nor the locks themselves are being rated or scored.** A high score on the specification evaluation of a system at a lock indicates that the system reflects the state-of-the-art. The performance evaluations are intended to give some insight into the experiences of lock operations staff regarding the equipment in use at the lock. It is important to remember that the performance evaluations are entirely subjective and are included for the sake of providing a more complete representation of the state of lock automation and control at the present time.

Simply surveying the specifications listed by several manufacturers and using those specifications that appeared most frequently with the mid-range-priced models led to the **Listed Specifications** used as the benchmarks for the specification evaluation forms.

Based on recommendations from several District Engineers and the lock operations staff, a weighting and scoring system was developed. It was designed to reflect the fact that some specifications and performance criteria are more relevant for a particular application than others. There are four scoring fields for each listed specification and performance criterion: weight, raw score, real score, and max score. The weight reflects the relative importance of the specification or performance criteria with respect to the others. The raw score has a slightly different meaning for the performance evaluations than it does for the specification evaluations. For the **specification** evaluations, the raw score reflects the degree to which the component measures up to the listed specifications. For the **performance** evaluations, the raw score is the value assigned to the response given for the performance of the device. The numerical values are as follows:

Performance Evaluation Raw Score Meaning

0 – poor

1 – fair

2 – excellent

Specifications Evaluation Raw Score Meaning

0 – fails to meet listed specification

1 – meets listed specification

2 – exceeds listed specification

The real score is calculated by multiplying the weight of the specification or criteria by the raw score. The max score is the maximum possible score for each specification or criteria.

For this study, it was necessary to identify the components of the automated control system whose performance and specifications are most critical to the overall performance of the system. Throughout the course of the survey, the evaluation forms and questions about the systems changed as the investigators gained more insight from the lock operations staff.

It was discovered early in the study that the manufacturer's credibility, longevity, and reputation were important when evaluating any system. However, those company qualities are difficult to quantify objectively. The **Manufacturer** field on both the performance and specification evaluation forms is intended to address this issue.

Since the specification forms for identical equipment will be identical, in those cases where locks have similar PLC and/or OI systems, the specification form for one lock is given followed by the performance evaluation form for all the locks with that type of equipment.

PLC Systems

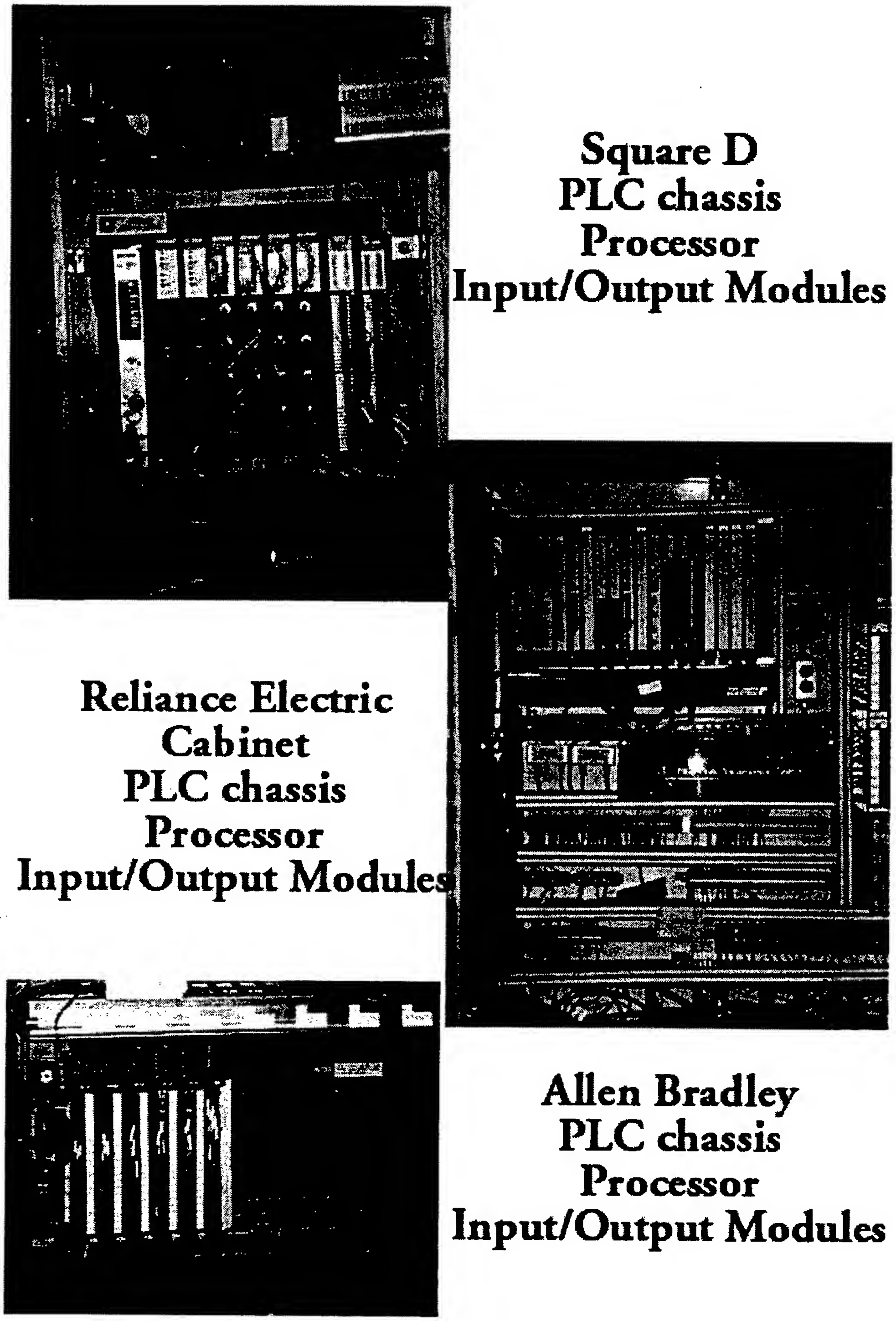


Figure B-1. Various PLC racks.

Your Personal PLC Tutor Teaches PLCs (http://www.plcs.net/index.shtml) defines a PLC as follows:

"A Programmable Logic Controller (PLC) is a device that was invented to replace the necessary sequential relay circuits for machine control. The PLC works by looking at its inputs and, depending upon their state, turning on/off its outputs. The user enters a program, usually via software, that gives the desired results... The PLC mainly consists of a CPU, memory areas, and appropriate circuits to receive input/output data."

After spending some time discussing the critical components of a PLC system with the St. Louis District, it became apparent that the processor is the most critical component of the PLC system. Its capabilities and limitations determine the effectiveness of the entire system. With that in mind, the **Processor** field on both the performance and specification evaluation forms is intended to address those specifications and performance criteria that have been found by lock operations and district engineering staff to be most crucial.

Several concepts were pointed out as being critical in the evaluation of the communications designed into a PLC system:

- Types of media converters (transceivers)
- Number of connections (points for possible failure)
- Network topology (bus, star, hybrid, etc.)
- Interconnection type (twisted pair, fiber optic, coaxial, etc.)
- Number and quality of components
- Redundancy
- Overall system robustness

These characteristics are also difficult to quantify objectively. A system whose network design is deterministic in nature can best deal with each question. This means that when there are several nodes in the PLC system that each one can communicate directly with each other without having communications hubs to convert the data. The fewer components in the network the lower the likelihood of a system failure. Furthermore, a deterministic network lends itself to having a modular design. In this case, all of the data conversion and communication

hardware is contained within modules that can be readily exchanged in the event of failure and are easily diagnosed to determine when a failure has occurred. This is a key advantage of PLC systems in general. However, a PLC system could operate without modularity in its design. The **Network Design** field is intended to address the necessity for system communication with integrity and adequate redundancy to insure minimum down time due to component failure. The **System Design** field is intended to treat the overall system.

The PLC system can only perform those functions for which it can be programmed. Each PLC system manufacturer has proprietary programming software for their systems. As is the case with all software, the programming software's lifetime is much shorter than that of the hardware. With each new generation of programming software, some capabilities are improved or eliminated. Several functions were suggested as being good to have for lock operation:

- A full-featured instruction set
- Fast learning curve of software
- Security levels
- Ability to annotate/document programming code
- Remote access to features
- Troubleshooting, diagnostic, and data logging features
- Capability to take advantage of Windows functions
- Programming integration into the OI (i.e., edits in programming or OI are automatically upgraded in the other)
- Compatibility of the programming driver with the network and system (i.e., programming can be accomplished from anywhere on the network).

The **Programming Software** field on the performance and specifications evaluation forms is aimed at dealing with them as compactly as possible. Tables B-1 through B-26 contain the lock evaluation forms for the PLCs.

Allen Bradley Systems

Table B-1. Specifications Form for PLC systems at Locks 24 and 25.

Detailed Specifications Score for PLC systems at Locks 24 and 25				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer: Allen Bradley				
Has been producing PLC systems for 10 years	2	2	4	4
Has product distributor within 50 miles of lock	3	1	3	3
Business on 4 or more continents	1	1	1	1
Processor : Allen Bradley PLC-5/80				
Self-diagnostic features indicating mode of operation and system faults	1	1	1	2
Battery-backed RAM capable of storing 1000 rungs of ladder logic	3	2	6	6
Scan rate of one thousands rungs per 30 miliseconds	2	2	4	4
built in RS-232 (or RS-422) serial communication port	1	1	1	2
Full math functions (addition,subtraction,multiplaction, division)	3	1	3	6
Supports online programming, I/O forcing, relay ladder logic, up/down conters	3	2	6	6
Network Design				
Allows for direct processor to processor communication	3	1	3	3
2 communications lines between I/O points	2	0	0	2
Supports remote access to all programming features	1	1	1	1
All fiber optic communications lines	1	1	1	1
System Design				
Modular Design	3	1	3	3
Lightning/surge protection	3	1	3	3
Programming Software: Allen Bradley RSLogics 5				
Runs on Windows NT	1	1	1	1
Supports different levels of security access	3	1	3	3
Automatically integrates changes in ladder logic programming into MMI software	1	0	0	1
SCORE			44	52

Table B-2. Performance Form for PLC System at Lock 24.

Detailed performance score for PLC system at Lock 24 visited 26 May 1999				
Evaluation Criteria	Weight	Raw Score	Real Score	Max Score
Manufacturer: Allen Bradley				
How would you rate the technical support	1	2	2	2
How ould you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	2	2	4	4
Processor Allen Bradley PLC-5/80				
How would you rate the dependability of the self-diagnosics messages	1	2	2	2
How would you rate the processor's tendency to crash	2	2	4	4
Network Design				
How would you rate the effectiveness of the network topology	1	2	2	2
How would you rate the tendency of network components to fail	2	2	4	4
System Design				
How would you rate the system's capacity to accommodate more modules	2	2	4	4
How would you rate the system's built-in battery back-up	3	2	6	6
How would you rate the physical size and layout of the system	1	2	2	2
Programming Software: Allen Bradley RSLogics 5				
How would you rate the difficulty of learning to use the software	3	2	6	6
How would you rate the clairityof icons and menus	3	2	6	6
How would you rate the flexibility of adding to and changing the ladder logic	2	2	4	4
SCORE			52	52

Table B-3. Performance Form for PLC System at Lock 25.

Detailed performance score for PLC system at Lock 25 visited 26 May 1999				
Evaluation Criteria	Weight	Raw Score	Real Score	Max Score
Manufacturer : Allen Bradley				
How would you rate the technical support	1	2	2	2
How ould you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	2	1	2	4
Processor Allen Bradley PLC-5/80				
How would you rate the dependability of the self-diagnosics messages	1	2	2	2
How would you rate the processor's tendency to crash	2	2	4	4
Network Design				
How would you rate the effectiveness of the network topology	1	2	2	2
How would you rate the tendency of network components to fail	2	1	2	4
System Design				
How would you rate the system's capacity to accommodate more modules	2	2	4	4
How would you rate the system's built-in battery back-up	3	2	6	6
How would you rate the physical size and layout of the system	1	2	2	2
Programming Software: Allen Bradley RSLogics 5				
How would you rate the difficulty of learning to use the software	3	2	6	6
How would you rate the clairityof icons and menus	3	2	6	6
How would you rate the flexibility of adding to and changing the ladder logic	2	2	4	4
SCORE			48	52

Table B-4. Specifications Form for PLC Systems at Leland-Bowman and Calcasieu Locks.

Detailed Specifications Score for PLC systems at Calcasieu and Leland-Bowman Locks				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer: Allen Bradley				
Has been producing PLC systems for 10 years	2	2	4	4
Has product distributor within 50 miles of lock	3	1	3	3
Business on 4 or more continents	1	1	1	1
Processor Allen Bradley PLC-5/40				
Self-diagnostic features indicating mode of operation and system faults	1	1	1	2
Battery-backed RAM capable of storing 1000 rungs of ladder logic	3	2	6	6
Scan rate of one thousands rungs per 30 miliseconds	2	2	4	4
built in RS-232 (or RS-422) serial communication port	1	1	1	2
Full math functions (addition,subtraction,multiplaction, divistion)	3	1	3	6
Supports online programming, I/O forcing, relay ladder logic, up/down conters	3	2	6	6
Network Design				
Allows for direct processor to processor communication	3	1	3	3
2 communications lines between I/O points	2	0	0	2
Supports remote access to all programming features	1	1	1	1
All fiber optic communications lines	1	1	1	1
System Design				
Modular Design	3	1	3	3
Lightning/surge protection	3	1	3	3
Programming Software: Allen Bradley 6200 Series				
Runs on Windows NT	1	0	0	1
Supports different levels of security access	3	1	3	3
Automatically integrates changes in ladder logic programming into MMI software	1	0	0	1
SCORE			43	52

Table B-5. Performance Form for PLC System at Calcasieu Lock.

Detailed Performance Score for PLC system at Calcasieu Lock visited 17 March 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer: Allen Bradley				
How would you rate the technical support	1	2	2	2
How ould you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	2	2	4	4
Processor Allen Bradley PLC-5/40				
How would you rate the dependability of the self-diagnosics messages	1	2	2	2
How would you rate the processor's tendency to crash	2	2	4	4
Network Design				
How would you rate the effectiveness of the network topology	1	2	2	2
How would you rate the tendency of network components to fail	2	2	4	4
System Design				
How would you rate the system's capacity to accommodate more modules	2	2	4	4
How would you rate the system's built-in battery back-up	3	2	6	6
How would you rate the physical size and layout of the system	1	2	2	2
Programming Software: Allen Bradley 6200 Series				
How would you rate the difficulty of learning to use the software	3	1	3	6
How would you rate the clairityof icons and menus	3	2	6	6
How would you rate the flexibility of adding to and changing the ladder logic	2	2	4	4
SCORE			49	52

Table B-6. Performance Form for PLC System at Leland-Bowman Lock.

Detailed Performance Score for PLC system at Leland-Bowman Lock visited 17 March 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer: Allen Bradley				
How would you rate the technical support	1	2	2	2
How culd you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	2	2	4	4
Processor : Allen Bradley PLC-5/40				
How would you rate the dependability of the self-diagnosics messages	1	2	2	2
How would you rate the processor's tendency to crash	2	2	4	4
Network Design				
How would you rate the effectiveness of the network topology	1	2	2	2
How would you rate the tendency of network components to fail	2	2	4	4
System Design				
How would you rate the system's capacity to accommodate more modules	2	2	4	4
How would you rate the system's built-in battery back-up	3	2	6	6
How would you rate the physical size and layout of the system	1	2	2	2
Programming Software: Allen Bradley 6200 Series				
How would you rate the difficulty of learning to use the software	3	1	3	6
How would you rate the clarityof icons and menus	3	2	6	6
How would you rate the flexibility of adding to and changing the ladder logic	2	2	4	4
SCORE			49	52

Table B-7. Specifications Form for PLC System at Lockport Lock.

Detailed Specifications Score for PLC system at Lockport Lock visited 16 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer: Allen Bradley				
Has been producing PLC systems for 10 years	2	2	4	4
Has product distributor within 50 miles of lock	3	1	3	3
Business on 4 or more continents	1	1	1	1
Processor : Allen Bradley PLC-3				
Self-diagnostic features indicating mode of operation and system faults	1	1	1	2
Battery-backed RAM capable of storing 1000 rungs of ladder logic	3	0	0	6
Scan rate of one thousands rungs per 30 miliseconds	2	0	0	4
built in RS-232 (or RS-422) serial communication port	1	1	1	2
Full math functions (addition,subtraction,multiplaction, divistion)	3	1	3	6
Supports online programming, I/O forcing, relay ladder logic, up/down conters	3	0	0	6
Network Design				
Allows for direct processor to processor communication	3	0	0	3
2 communications lines between I/O points	2	0	0	2
Supports remote access to all programming features	1	1	1	1
All fiber optic communications lines	1	0	0	1
System Design				
Modular Design	3	1	3	3
Lightning/surge protection	3	0	0	3
Programming Software: Allen Bradley AI Series by ICOM				
Runs on Windows NT	1	0	0	1
Supports different levels of security access	3	0	0	3
Automatically integrates changes in ladder logic programming into MMI software	1	0	0	1
SCORE			17	52

Table B-8. Performance Form for PLC System at Lockport Lock.

Detailed Performance Score for PLC system at Lockport Lock visited 16 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer: Allen Bradley				
How would you rate the technical support	1	2	2	2
How ould you rate the access to spare parts	3	1	3	6
How would you rate the compatibility of new replacements for old parts	2	1	2	4
Processor Allen Bradley PLC-3				
How would you rate the dependability of the self-diagnosics messages	1	2	2	2
How would you rate the processor's tendency to crash	2	2	4	4
Network Design				
How would you rate the effectiveness of the network topology	1	1	1	2
How would you rate the tendency of network components to fail	2	2	4	4
System Design				
How would you rate the system's capacity to accommodate more modules	2	1	2	4
How would you rate the system's built-in battery back-up	3	2	6	6
How would you rate the physical size and layout of the system	1	1	1	2
Programming Software: Allen Bradley AI Series by ICOM				
How would you rate the difficulty of learning to use the software	3	2	6	6
How would you rate the clairityof icons and menus	3	2	6	6
How would you rate the flexibility of adding to and changing the ladder logic	2	2	4	4
SCORE			**43**	**52**

Table B-9. Specifications Form for PLC System at Port St. Lucie Lock.

Detailed Specifications score for PLC system at Port St. Lucie Lock visited 19 February 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer: Allen Bradley				
Has been producing PLC systems for 10 years	2	1	2	4
Has product distributor within 50 miles of lock	3	0	0	3
Business on 4 or more continents	1	1	1	1
Processor Allen Bradley PLC-2/30				
Self-diagnostic features indicating mode of operation and system faults	1	1	1	2
Battery-backed RAM capable of storing 1000 rungs of ladder logic	3	0	0	6
Scan rate of one thousands rungs per 30 miliseconds	2	0	0	4
built in RS-232 (or RS-422) serial communication port	1	0	0	2
Full math functions (addition,subtraction,multiplaction, divistion)	3	0	0	6
Supports online programming, I/O forcing, relay ladder logic, up/down conters	3	0	0	6
Network Design				
Allows for direct processor to processor communication	3	0	0	3
2 communications lines between I/O points	2	0	0	2
Supports remote access to all programming features	1	0	0	1
All fiber optic communications lines	1	0	0	1
System Design				
Modular Design	3	1	3	3
Lightning/surge protection	3	0	0	3
Programming Software: Allen Bradley				
Runs on Windows NT	1	0	0	1
Supports different levels of security access	3	0	0	3
Automatically integrates changes in ladder logic programming into MMI software	1	0	0	1
SCORE			**7**	**52**

Table B-10. Performance Form for PLC System at Port St. Lucie Lock.

Detailed Performance Score for PLC system at Port St. Lucie Lock visited 19 February 1999				
Evaluation Criteria	Weight	Raw Score	Real Score	Max Score
Manufacturer: Allen Bradley				
How would you rate the technical support	1	0	0	2
How ould you rate the access to spare parts	3	0	0	6
How would you rate the compatibility of new replacements for old parts	2	1	2	4
Processor: Allen Bradley PLC-2/30				
How would you rate the dependability of the self-diagnosics messages	1	1	1	2
How would you rate the processor's tendency to crash	2	2	4	4
Network Design Score				
How would you rate the effectiveness of the network topology	1	2	2	2
How would you rate the tendency of network components to fail	2	2	4	4
System Design Score				
How would you rate the system's capacity to accommodate more modules	2	1	2	4
How would you rate the system's built-in battery back-up	3	2	6	6
How would you rate the physical size and layout of the system	1	2	2	2
Programming Software: Allen Bradley				
How would you rate the difficulty of learning to use the software	3	1	3	6
How would you rate the clairityof icons and menus	3	1	3	6
How would you rate the flexibility of adding to and changing the ladder logic	2	1	2	4
SCORE			31	52

Square D Systems

Table B-11. Specifications Form for PLC Systems at Barkley, Bonneville, Pickwick, and Wheeler Locks.

Detailed Specifications Score for PLC System at Barkley, Bonneville, Pickwick, and Wheeler Locks and Dams				
Listed Specifications	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer : Square D				
Has been producing PLC systems for 10 years	2	2	4	4
Has product distributor within 50 miles of lock	3	1	3	3
Business on 4 or more continents	1	1	1	1
Processor : Square D SY/MAX 400				
Self-diagnostic features indicating mode of operation and system faults	1	2	2	2
Battery-backed RAM capable of storing 1000 rungs of ladder logic	3	2	6	6
Scan rate of one thousands rungs per 30 miliseconds	2	2	4	4
built in RS-232 (or RS-422) serial communication port	1	2	2	2
Full math functions (addition,subtraction,multiplaction, divistion)	3	2	6	6
Supports online programming, I/O forcing, relay ladder logic, up/down conters	3	2	6	6
Network Design				
Allows for direct processor to processor communication	3	1	3	3
2 communications lines between I/O points	2	0	0	2
Supports remote access to all programming features	1	0	0	1
All fiber optic communications lines	1	1	1	1
System Design				
Modular Design	3	1	3	3
Lightning/surge protection	3	1	3	3
Programming Software: Square D SY/MATE PLUS				
Runs on Windows NT	1	0	0	1
Supports different levels of security access	3	1	3	3
Automatically integrates changes in ladder logic programming into MMI software	1	0	0	1
SCORE			**47**	**52**

Table B-12. Performance Form for PLC System at Barkley Lock.

Detailed Performance Score for PLC system at Barkley Dam and Lake Barkley visited 18 February 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer Score				
How would you rate the technical support	1	2	2	2
How ould you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	2	2	4	4
Processor Score: Square D SY/MAX 400				
How would you rate the dependability of the self-diagnosics messages	1	2	2	2
How would you rate the processor's tendency to crash	2	2	4	4
Network Design Score				
How would you rate the effectiveness of the network topology	1	2	2	2
How would you rate the tendency of network components to fail	2	2	4	4
System Design Score				
How would you rate the system's capacity to accommodate more modules	2	2	4	4
How would you rate the system's built-in battery back-up	3	2	6	6
How would you rate the physical size and layout of the system	1	2	2	2
Programming Software: Square D SY/MATE PLUS				
How would you rate the difficulty of learning to use the software	3	2	6	6
How would you rate the clairityof icons and menus	3	2	6	6
How would you rate the flexibility of adding to and changing the ladder logic	2	2	4	4
SCORE			52	52

Table B-13. Performance Form for PLC System at Bonneville Lock.

Detailed Performance Score for PLC system at Bonneville Lock and Dam visited 1 March 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacture: Square D				
How would you rate the technical support	1	2	2	2
How ould you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	2	2	4	4
Processor Square D SY/MAX 400				
How would you rate the dependability of the self-diagnosics messages	1	2	2	2
How would you rate the processor's tendency to crash	2	2	4	4
Network Design				
How would you rate the effectiveness of the network topology	1	2	2	2
How would you rate the tendency of network components to fail	2	2	4	4
System Design				
How would you rate the system's capacity to accommodate more modules	2	2	4	4
How would you rate the system's built-in battery back-up	3	1	3	6
How would you rate the physical size and layout of the system	1	2	2	2
Programming Software: Square D SY/MATE PLUS				
How would you rate the difficulty of learning to use the software	3	2	6	6
How would you rate the clairityof icons and menus	3	2	6	6
How would you rate the flexibility of adding to and changing the ladder logic	2	2	4	4
SCORE			49	52

Table B-14. Performance Form for PLC System at Pickwick Lock.

Detailed Performance Score for PLC system at Pickwick Landing Lock and Dam visited 21 June 1999				
Evaluation Criteria	Weight	Raw Score	Real Score	Max Score
Manufacturer: Square D				
How would you rate the technical support	1	2	2	2
How ould you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	2	2	4	4
Processor Square D SY/MAX 400				
How would you rate the dependability of the self-diagnosics messages	1	2	2	2
How would you rate the processor's tendency to crash	2	2	4	4
Network Design				
How would you rate the effectiveness of the network topology	1	2	2	2
How would you rate the tendency of network components to fail	2	2	4	4
System Design				
How would you rate the system's capacity to accommodate more modules	2	2	4	4
How would you rate the system's built-in battery back-up	3	2	6	6
How would you rate the physical size and layout of the system	1	2	2	2
Programming Software: Square D SY/MATE PLUS				
How would you rate the difficulty of learning to use the software	3	2	6	6
How would you rate the clairityof icons and menus	3	2	6	6
How would you rate the flexibility of adding to and changing the ladder logic	2	2	4	4
SCORE			52	52

Table B-15. Performance Form for PLC System at Wheeler Lock.

Detailed Performance Score for PLC system at Wheeler Lock and Dam visited 22 June 1999				
Evaluation Criteria	Weight	Raw Score	Real Score	Max Score
Manufacturer: Square D				
How would you rate the technical support	1	2	2	2
How ould you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	2	2	4	4
Processor Square D SY/MAX 400				
How would you rate the dependability of the self-diagnosics messages	1	2	2	2
How would you rate the processor's tendency to crash	2	2	4	4
Network Design				
How would you rate the effectiveness of the network topology	1	2	2	2
How would you rate the tendency of network components to fail	2	2	4	4
System Design				
How would you rate the system's capacity to accommodate more modules	2	2	4	4
How would you rate the system's built-in battery back-up	3	2	6	6
How would you rate the physical size and layout of the system	1	2	2	2
Programming Software: Square D SY/MATE PLUS				
How would you rate the difficulty of learning to use the software	3	2	6	6
How would you rate the clairityof icons and menus	3	2	6	6
How would you rate the flexibility of adding to and changing the ladder logic	2	2	4	4
SCORE			52	52

Table B-16. Specifications Form for PLC System at Winfield Locks.

Detailed Specifications Score for PLC system at Winfield Locks and Dam visited 4 June 1999				
Listed Specifications	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer: Square D				
Has been producing PLC systems for 10 years	2	2	4	4
Has product distributor within 50 miles of lock	3	0	0	3
Business on 4 or more continents	1	1	1	1
Processor: Square D SY/MAX 444				
Self-diagnostic features indicating mode of operation and system faults	1	2	2	2
Battery-backed RAM capable of storing 1000 rungs of ladder logic	3	2	6	6
Scan rate of one thousands rungs per 30 miliseconds	2	2	4	4
built in RS-232 (or RS-422) serial communication port	1	2	2	2
Full math functions (addition,subtraction,multiplaction, divistion)	3	2	6	6
Supports online programming, I/O forcing, relay ladder logic, up/down conters	3	2	6	6
Network Desig				
Allows for direct processor to processor communication	3	1	3	3
2 communications lines between I/O points	2	0	0	2
Supports remote access to all programming features	1	0	0	1
All fiber optic communications lines	1	1	1	1
System Design				
Modular Design	3	1	3	3
Lightning/surge protection	3	1	3	3
Programming Software: Square D SY/MATE PLUS				
Runs on Windows NT	1	0	0	1
Supports different levels of security access	3	1	3	3
Automatically integrates changes in ladder logic programming into MMI software	1	0	0	1
SCORE			44	52

Table B-17. Performance Form for PLC System at Winfield Locks.

Detailed Performance Score for PLC system at Winfield Locks and Dam visited 4 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer: Square D				
How would you rate the technical support	1	2	2	2
How ould you rate the access to spare parts	3	1	3	6
How would you rate the compatibility of new replacements for old parts	2	1	2	4
Processor: Square D SY/MAX 444				
How would you rate the dependability of the self-diagnosics messages	1	2	2	2
How would you rate the processor's tendency to crash	2	2	4	4
Network Design				
How would you rate the effectiveness of the network topology	1	2	2	2
How would you rate the tendency of network components to fail	2	2	4	4
System Design				
How would you rate the system's capacity to accommodate more modules	2	2	4	4
How would you rate the system's built-in battery back-up	3	2	6	6
How would you rate the physical size and layout of the system	1	2	2	2
Programming Software: Square D SY/MATE PLUS				
How would you rate the difficulty of learning to use the software	3	2	6	6
How would you rate the clairityof icons and menus	3	2	6	6
How would you rate the flexibility of adding to and changing the ladder logic	2	2	4	4
SCORE			47	52

Table B-18. Specifications Form for PLC System at Lock 1.

Detailed Specifications Score for PLC system at Lock 1 visited 2 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer: Square D				
Has been producing PLC systems for 10 years	2	2	4	4
Has product distributor within 50 miles of lock	3	1	3	3
Business on 4 or more continents	1	1	1	1
Processor : Square D SY/MAX 600				
Self-diagnostic features indicating mode of operation and system faults	1	2	2	2
Battery-backed RAM capable of storing 1000 rungs of ladder logic	3	2	6	6
Scan rate of one thousands rungs per 30 miliseconds	2	0	0	4
built in RS-232 (or RS-422) serial communication port	1	1	1	2
Full math functions (addition,subtraction,multiplaction, divistion)	3	2	6	6
Supports online programming, I/O forcing, relay ladder logic, up/down conters	3	2	6	6
Network Design				
Allows for direct processor to processor communication	3	1	3	3
2 communications lines between I/O points	2	0	0	2
Supports remote access to all programming features	1	1	1	1
All fiber optic communications lines	1	1	1	1
System Design				
Modular Design	3	1	3	3
Lightning/surge protection	3	1	3	3
Programming Software: Square D SY/MATE PLUS				
Runs on Windows NT	1	0	0	1
Supports different levels of security access	3	1	3	3
Automatically integrates changes in ladder logic programming into MMI software	1	0	0	1
SCORE			43	52

Table B-19. Performance Form for PLC System at Lock 1.

Detailed Performance Score for PLC system at Lock 1(St. Paul, MN) visited 2 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer: Square D				
How would you rate the technical support	1	2	2	2
How ould you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	2	2	4	4
Processor Square D SY/MAX 600				
How would you rate the dependability of the self-diagnosics messages	1	2	2	2
How would you rate the processor's tendency to crash	2	2	4	4
Network Design				
How would you rate the effectiveness of the network topology	1	1	1	2
How would you rate the tendency of network components to fail	2	2	4	4
System Design				
How would you rate the system's capacity to accommodate more modules	2	2	4	4
How would you rate the system's built-in battery back-up	3	2	6	6
How would you rate the physical size and layout of the system	1	2	2	2
Programming Software: Square D SY/MATE PLUS				
How would you rate the difficulty of learning to use the software	3	2	6	6
How would you rate the clarityof icons and menus	3	2	6	6
How would you rate the flexibility of adding to and changing the ladder logic	2	2	4	4
SCORE			51	52

Table B-20. Specifications Form for PLC Systems at Melvin Price Locks and Locks No. 27.

Detailed Specifications Score for PLC systems at Melvin Price Locks and Dam and Locks No. 27				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer: Square D				
Has been producing PLC systems for 10 years	2	2	4	4
Has product distributor within 50 miles of lock	3	1	3	3
Business on 4 or more continents	1	1	1	1
Processor : Square D SY/MAX 650				
Self-diagnostic features indicating mode of operation and system faults	1	2	2	2
Battery-backed RAM capable of storing 1000 rungs of ladder logic	3	2	6	6
Scan rate of one thousands rungs per 30 miliseconds	2	2	4	4
built in RS-232 (or RS-422) serial communication port	1	2	2	2
Full math functions (addition,subtraction,multiplaction, divistion)	3	2	6	6
Supports online programming, I/O forcing, relay ladder logic, up/down conters	3	2	6	6
Network Design				
Allows for direct processor to processor communication	3	1	3	3
2 communications lines between I/O points	2	1	2	2
Supports remote access to all programming features	1	1	1	1
All fiber optic communications lines	1	1	1	1
System Design				
Modular Design	3	1	3	3
Lightning/surge protection	3	1	3	3
Programming Software: SY/MATE PLUS				
Runs on Windows NT	1	1	1	1
Supports different levels of security access	3	1	3	3
Automatically integrates changes in ladder logic programming into MMI software	1	0	0	1
SCORE			51	52

Table B-21. Performance Form for PLC System at Melvin Price Locks.

Detailed Performance Score for PLC system at Melvin Price Locks and Dam visited 25 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer: Square D				
How would you rate the technical support	1	2	2	2
How ould you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	2	2	4	4
Processor : Square D SY/MAX 650				
How would you rate the dependability of the self-diagnosics messages	1	2	2	2
How would you rate the processor's tendency to crash	2	2	4	4
Network Design				
How would you rate the effectiveness of the network topology	1	2	2	2
How would you rate the tendency of network components to fail	2	2	4	4
System Design				
How would you rate the system's capacity to accommodate more modules	2	2	4	4
How would you rate the system's built-in battery back-up	3	2	6	6
How would you rate the physical size and layout of the system	1	2	2	2
Programming Software: Square D SY/MATE PLUS				
How would you rate the difficulty of learning to use the software	3	2	6	6
How would you rate the clairityof icons and menus	3	2	6	6
How would you rate the flexibility of adding to and changing the ladder logic	2	2	4	4
SCORE			52	52

Table B-22. Performance Score for PLC System at Locks No. 27.

Detailed Performance Score for PLC System at Locks No. 27 visited 26 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer: Square D				
How would you rate the technical support	1	2	2	2
How ould you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	2	1	2	4
Processor: Square D SY/MAX 650				
How would you rate the dependability of the self-diagnosics messages	1	1	1	2
How would you rate the processor's tendency to crash	2	2	4	4
Network Design				
How would you rate the effectiveness of the network topology	1	2	2	2
How would you rate the tendency of network components to fail	2	2	4	4
System Design				
How would you rate the system's capacity to accommodate more modules	2	2	4	4
How would you rate the system's built-in battery back-up	3	2	6	6
How would you rate the physical size and layout of the system	1	2	2	2
Programming Software: Square D SY/MATE PLUS				
How would you rate the difficulty of learning to use the software	3	2	6	6
How would you rate the clairityof icons and menus	3	2	6	6
How would you rate the flexibility of adding to and changing the ladder logic	2	2	4	4
SCORE			**49**	**52**

Table B-23. Specifications Form for PLC System at Wilson (aux) Lock.

Detailed Specifications Score for PLC System at Wilson (aux) Lock visited 22 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer Score: Square D				
Has been producing PLC systems for 10 years	2	2	4	4
Has product distributor within 50 miles of lock	3	1	3	3
Business on 4 or more continents	1	1	1	1
Processor Score: SY/MAX 500				
Self-diagnostic features indicating mode of operation and system faults	1	1	1	2
Battery-backed RAM capable of storing 1000 rungs of ladder logic	3	1	3	6
Scan rate of one thousands rungs per 30 miliseconds	2	2	4	4
built in RS-232 (or RS-422) serial communication port	1	1	1	2
Full math functions (addition,subtraction,multiplaction, divistion)	3	1	3	6
Supports online programming, I/O forcing, relay ladder logic, up/down conters	3	1	3	6
Network Design Score				
Allows for direct processor to processor communication	3	1	3	3
2 communications lines between I/O points	2	0	0	2
Supports remote access to all programming features	1	0	0	1
All fiber optic communications lines	1	0	0	1
System Design Score				
Modular Design	3	1	3	3
Lightning/surge protection	3	1	3	3
Programming Software				
Runs on Windows NT	1	0	0	1
Supports different levels of security access	3	1	3	3
Automatically integrates changes in ladder logic programming into MMI software	1	0	0	1
SCORE			**35**	**52**

Table B-24. Performance Form for PLC System at Wilson (aux) Lock.

Detailed Performance Score for PLC System at Wilson (aux) Lock visited 22 June 1999				
Evaluation Criteria	Weight	Raw Score	Real Score	Max Score
Manufacturer Score: Square D				
How would you rate the technical support	1	2	2	2
How ould you rate the access to spare parts	3	1	3	6
How would you rate the compatibility of new replacements for old parts	2	1	2	4
Processor Score: SY/MAX 500				
How would you rate the dependability of the self-diagnosics messages	1	2	2	2
How would you rate the processor's tendency to crash	2	2	4	4
Network Design Score				
How would you rate the effectiveness of the network topology	1	2	2	2
How would you rate the tendency of network components to fail	2	2	4	4
System Design Score				
How would you rate the system's capacity to accommodate more modules	2	2	4	4
How would you rate the system's built-in battery back-up	3	2	6	6
How would you rate the physical size and layout of the system	1	2	2	2
Programming Software				
How would you rate the difficulty of learning to use the software	3	2	6	6
How would you rate the clarityof icons and menus	3	2	6	6
How would you rate the flexibility of adding to and changing the ladder logic	2	2	4	4
SCORE			47	52

Reliance Electric System

Table B-25. Specifications Form for PLC System at Wilson (main) Lock.

Detailed specifications score for PLC system at Wilson (main) Lock visited 21 June 1999				
Listed Specifications	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer: Reliance Electric				
Has been producing PLC systems for 10 years	2	1	2	4
Has product distributor within 50 miles of lock	3	1	3	3
Business on 4 or more continents	1	1	1	1
Processor: Reliance Electric 7010				
Self-diagnostic features indicating mode of operation and system faults	1	1	1	2
Battery-backed RAM capable of storing 1000 rungs of ladder logic	3	1	3	6
Scan rate of one thousands rungs per 30 miliseconds	2	1	2	4
built in RS-232 (or RS-422) serial communication port	1	1	1	2
Full math functions (addition,subtraction,multiplaction, divistion)	3	1	3	6
Supports online programming, I/O forcing, relay ladder logic, up/down conters	3	2	6	6
Network Design				
Allows for direct processor to processor communication	3	1	3	3
2 communications lines between I/O points	2	1	2	2
Supports remote access to all programming features	1	1	1	1
All fiber optic communications lines	1	1	1	1
System Design				
Modular Design	3	1	3	3
Lightning/surge protection	3	1	3	3
Programming Software (programming handled by contractor)				
Runs on Windows NT	1	0	0	1
Supports different levels of security access	3	1	3	3
Automatically integrates changes in ladder logic programming into MMI software	1	0	0	1
SCORE			**38**	**52**

Table B-26. Performance Form for PLC System at Wilson (main) Lock.

Detailed Performance Score for PLC system at Wilson (main) Lock visited 21 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Real Score**	**Max Score**
Manufacturer: Reliance Electric				
How would you rate the technical support	1	2	2	2
How ould you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	2	2	4	4
Processor: Reliance Electric 7010				
How would you rate the dependability of the self-diagnosics messages	1	2	2	2
How would you rate the processor's tendency to crash	2	2	4	4
Network Design				
How would you rate the effectiveness of the network topology	1	2	2	2
How would you rate the tendency of network components to fail	2	2	4	4
System Design				
How would you rate the system's capacity to accommodate more modules	2	2	4	4
How would you rate the system's built-in battery back-up	3	2	6	6
How would you rate the physical size and layout of the system	1	2	2	2
Programming Software (programming handled by contractor)				
How would you rate the difficulty of learning to use the software	3	2	6	6
How would you rate the clairityof icons and menus	3	2	6	6
How would you rate the flexibility of adding to and changing the ladder logic	2	2	4	4
SCORE			**52**	**52**

Operator's Interface (OI) Systems

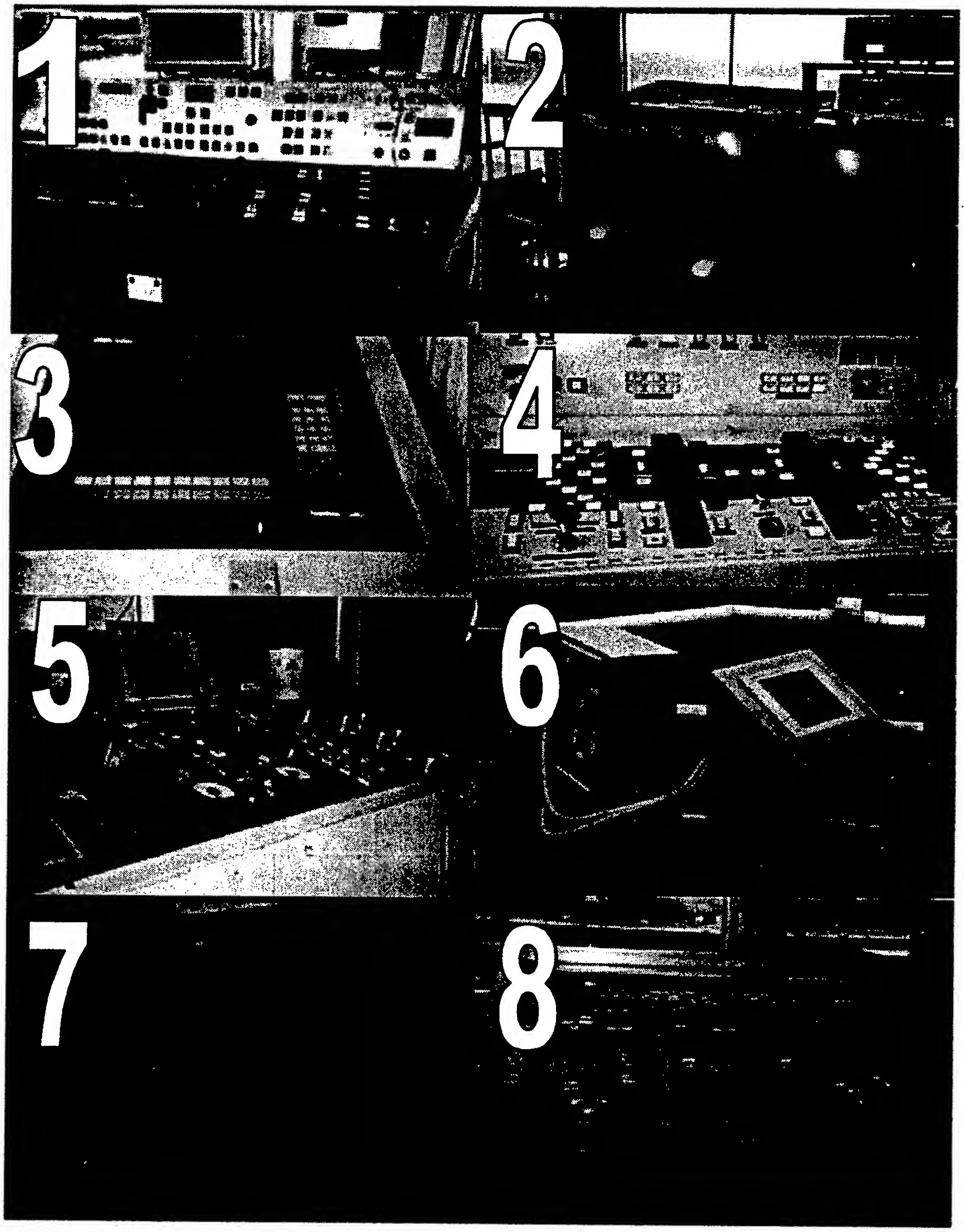


Figure B-2. Various OI Systems: (1) Pushbutton control panel, (2) GUI-driven control panel, (3) GUI-driven control panel, (4) Pushbutton control panel, (5) Pushbutton control panel, (6) GUI-driven control panel, (7) GUI-driven control panel, (8) Pushbutton control panel.

For this study, the operator's interface (OI) of a system is the means by which the lock operator issues control signals to and receives status feedback from the lock equipment. Examples are shown in Figure 2. Based on this definition, both modern GUI-driven OI systems and the traditional hardwired pushbutton control panels (that all locks once used) could be compared and evaluated.

The GUI-driven OI systems are the current latest technology. At the heart of these systems is a supervisory control and data acquisition (SCADA) software package. This software package usually runs on a PC used as the data server for the control system of the lock. Included in the software package is usually a graphical user interface (GUI) development tool with which the control system designer can create control display screens to replace and, in some cases, complement the pushbutton control panel that had been in place at the lock. OI software comes with a multitude of functions including, but not limited to, the following:

- Operation on the Windows NT operating system
- A "heartbeat" function (regular system status indication)
- Windows functionality
- Trending capabilities
- Support of multiple input devices (mouse, keyboard, voice, touchscreen, etc.)
- Data logging
- Alarm point setting
- Various levels of security access
- Logic analysis
- Mathematical capabilities

The **Listed Specifications** for the OI software at those locks with GUI-driven OI systems include those functions among these that have proven to be the most useful.

Along with the software requirements and functionality, the PC that the software is to run is a critical component of the GUI-driven OI system. Along with

PC specifications such as memory, processor speed, and Operating System, the conditions at a lock introduce the need for the PC to be capable of operation in harsh environments. The **Chassis** field on the specification forms is intended to address this. The specifications listed there are intended to reflect the need for an Industrial Personal Computer (IPC) to insure the reliability of the PC in the lock environment. The purpose of the **PC Components** field is to evaluate the compatibility of the PC with most GUI-driven OI software on the market now and upgrades that will be introduced in the near future.

The monitor on which the GUI operates becomes a source of problems due to the fact that the lock is in operation 24 hours a day. In the early morning and late evening hours, lock control booths are subject to direct sunlight. This in turn forces the lock operations staff to deal with glare on their display screens. Additionally, since the monitors need to be on 24 hours a day, the screens are subject to higher burn-out and failure rates. In order for a GUI-driven OI to be plausible in the lock control booths, it must be designed to handle these issues. The **Monitor** field on the specification evaluation form addresses this.

The performance of the OI PC at those locks with GUI-driven OI systems is slightly different. The **PC Components** field of the performance evaluation form is intended to reflect the extra maintenance that the addition of another PC to lock control brought. The **Monitor** field of the evaluation form is intended to allow the lock operators to compare the new control screens with the old push-button control panels. The **Design** field of the performance evaluation form also addresses the practicality of the new equipment. The OI Evaluation Tables are contained in Tables B-27 through B-40.

GUI-Driven Control

Table-B-27. Specifications Forms for OI System at Locks 24 and 25.

Detailed Specifications Score for OI PC at Locks 24 and 25				
Listed Specifications	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score				
PC production for over 10 years	3	2	6	6
PC Components Score: ICS 7415K6-23V-B3				
120 MHz processor	1	2	2	2
64 MB RAM	1	1	2	1
365 MB Hard Drive	1	2	2	2
Ethernet and serial communications ports	1	1	1	1
Windows NT Operating System	3	1	3	3
Monitor Score: NEC LCD2000 (LA-2031JMW-1)				
30 MHz video bandwidth	3	2	6	6
60 Hz Vertical Scan Frequency	1	2	2	2
800X600 Pixel Maximum Resolution	1	2	2	2
70 Hz Horizontal Scan Frequency	1	2	2	2
Energy Star and VESA compliance	3	2	6	6
5-year Warranty	3	0	6	0
Chassis Score				
Passive Backplane	2	1	2	2
Rack Mountable	2	1	2	2
2 or More Fans in Cooling System	1	1	1	1
Dust Filtering system	1	1	1	1
Metal chassis	1	1	1	1
SCORE			**47**	**40**

Detailed Specifications Score for OI Software at Locks 24 and 25				
Listed Specifications	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Runs on Windows NT	2	1	2	2
Regular on-screen status notification	3	1	3	3
Can record patterns in user-software interactions	2	1	2	2
Minimum required processor speed of 100 MHz	2	1	2	2
Minimum required memory 24 MB	2	1	2	2
Minimum required hard disk space of 100 MB	2	1	2	2
Ability to set alarm points based on device/user inputs	2	1	2	2
Support of different Levels of Security Access	3	1	3	3
SCORE			**18**	**18**

Table B-28. Performance Forms for OI System at Lock No. 24.

Detailed Performance Score for OI Software at Lock 24 Visited 26 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
How would you rate the difficulty of learning to use the OI	3	2	6	6
How would you rate the clarity of the icons and menus of the OI	3	2	6	6
How would you rate the use of display space on the GUI	2	2	4	4
How would you rate the method by which changes in ladder logic are integated into the OI	1	2	2	2
How would you rate the OI's usefulness in locating faults detected by the sensors	3	2	6	6
SCORE			24	24

Detailed Performance Score for OI PC at Lock 24 visited 26 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score				
How would your rate the technical support	2	1	4	2
PC Components Score: ICS 7415K6-23V-B3				
How would you rate the dependability of the self-diagnosics messages	3	2	6	6
How would you rate the pc's tendency to crash	3	2	6	6
Monitor Score: NEC LCD2000 (LA-2031JMW-1)				
How would you rate the monitor's resistance to glare	3	1	6	3
How would you rate the visibility of the icons and menus on the monitor	3	1	6	3
How would you rate the "fit" of the monitor in the control room	1	2	2	2
Design Score				
How would you rate the PC's capacity to accommodate more peripheral cards	1	1	2	1
How would you rate the PC's built-in batter back-up	2	2	4	4
How would your rate the fit of the PC in the control room	1	2	2	2
How would you rate the PC's lightning/surge protection	2	2	4	4
SCORE			42	33

Table B-29. Performance Forms for OI System at Lock No. 25.

Detailed Performance Score for OI PC at Lock 25 Visited 26 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer: Industrial Computer Source				
How would your rate the technical support	2	1	4	2
PC Components Score: ICS 7415K6-23V-B3				
How would you rate the dependability of the self-diagnosics messages	3	2	6	6
How would you rate the pc's tendency to crash	3	2	6	6
Monitor Score: NEC LCD2000 (LA-2031JMW-1)				
How would you rate the monitor's resistance to glare	3	0	6	0
How would you rate the visibility of the icons and menus on the monitor	3	1	6	3
How would you rate the "fit" of the monitor in the control room	1	2	2	2
Design Score				
How would you rate the PC's capacity to accommodate more peripheral cards	1	1	2	1
How would you rate the PC's built-in batter back-up	2	2	4	4
How would your rate the fit of the PC in the control room	1	2	2	2
How would you rate the PC's lightning/surge protection	2	2	4	4
SCORE			42	30

Detailed Performance Score for OI Software at Lock 25 Visited 26 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
How would you rate the difficulty of learning to use the OI	3	2	6	6
How would you rate the clarity of the icons and menus of the OI	3	2	6	6
How would you rate the use of display space on the GUI	2	2	4	4
How would you rate the method by which changes in ladder logic are integated into the OI	1	2	2	2
How would you rate the OI's usefulness in locating faults detected by the sensors	3	2	6	6
SCORE			24	24

Table B-30. Specifications Forms for OI System at Melvin Price Locks.

Detailed specifications score for OI PC at Melvin Price Locks and Dam visited 26 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score				
PC production for over 10 years	3	1	6	3
PC Components Score: Industrial Computer Source				
120 MHz processor	1	2	2	2
64 MB RAM	1	2	2	2
365 MB Hard Drive	1	2	2	2
Ethernet and serial communications ports	1	1	1	1
Windows NT Operating System	3	1	3	3
Monitor Score: Intecolor Megatrend/2 E01923-20R				
30 MHz video bandwidth	3	2	6	6
60 Hz Vertical Scan Frequency	1	2	2	2
800X600 Pixel Maximum Resolution	1	1	2	1
70 Hz Horizontal Scan Frequency	1	0	2	0
Energy Star and VESA compliance	3	1	6	3
5-year Warranty	3	0	6	0
Chassis Score: ICS 7508-33H				
Passive Backplane	2	1	2	2
Rack Mountable	2	1	2	2
2 or More Fans in Cooling System	1	1	1	1
Dust Filtering system	1	1	1	1
Metal chassis	1	1	1	1
SCORE			47	32

Detailed specifications score for OI software at Melvin Price Locks and Dam visited 26 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Runs on Windows NT	2	1	2	2
Regular on-screen status notification	3	1	3	3
Can record patterns in user-software interactions	2	1	2	2
Minimum required processor speed of 100 MHz	2	1	2	2
Minimum required memory 24 MB	2	0	2	0
Minimum required hard disk space of 100 MB	2	0	2	0
Ability to set alarm points based on device/user inputs	2	1	2	2
Support of different Levels of Security Access	3	1	3	3
SCORE			18	14

Table B-31. Performance Forms for OI System at Melvin Price Locks.

Detailed Performance Score for OI PC at Melvin Price Locks and Dam visited 25 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score				
How would your rate the technical support	2	2	4	4
PC Components Score: Industrial Computer Source				
How would you rate the dependability of the self-diagnosics messages	3	2	6	6
How would you rate the pc's tendency to crash	3	2	6	6
Monitor Score: Intecolor Megatrend/2 E01923-20R				
How would you rate the monitor's resistance to glare	3	1	6	3
How would you rate the visibility of the icons and menus on the monitor	3	1	6	3
How would you rate the "fit" of the monitor in the control room	1	2	2	2
Design Score				
How would you rate the PC's capacity to accommodate more peripheral cards	1	1	2	1
How would you rate the PC's built-in batter back-up	2	2	4	4
How would your rate the fit of the PC in the control room	1	0	2	0
How would you rate the PC's lightning/surge protection	2	2	4	4
SCORE			**42**	**33**

Detailed Performance Score for OI software at Melvin Price Locks and Dam visited 25 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
How would you rate the difficulty of learning to use the OI	3	2	6	6
How would you rate the clarity of the icons and menus of the OI	3	2	6	6
How would you rate the use of display space on the GUI	2	2	4	4
How would you rate the way that changes in ladder logic are integated into the OI	1	2	2	2
How would you rate the OI's usefulness in locating faults detected by the sensors	3	2	6	6
SCORE			**24**	**24**

Table B-32. Specifications Form for OI System at Locks No. 27.

Detailed Specifications score for OI PC at Locks 27 visited 26 May 1999				
Listed Specifications	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer: Industrial Computer Source(ICS)				
PC production for over 10 years	3	1	3	3
PC Components: ICS (same as Melvin Price Locks and Dam)				
120 MHz processor	1	2	2	2
64 MB RAM	1	2	2	2
365 MB Hard Drive	1	2	2	2
Ethernet and serial communications ports	1	1	1	1
Windows NT Operating System	3	1	3	3
Monitor: Acer (obsolete model with no available specifications)				
30 MHz video bandwidth	3	0	6	0
60 Hz Vertical Scan Frequency	1	0	2	0
800X600 Pixel Maximum Resolution	1	0	2	0
70 Hz Horizontal Scan Frequency	1	0	2	0
Energy Star and VESA compliance	3	0	6	0
5-year Warranty	3	0	6	0
Chassis: ICS 7508-33H				
Passive Backplane	2	1	2	2
Rack Mountable	2	1	2	2
2 or More Fans in Cooling System	1	1	1	1
Dust Filtering system	1	1	1	1
Metal chassis	1	1	1	1
SCORE			**44**	**20**

Detailed Specifications Score for OI software running at Locks 27 visited 26 May 1999				
Listed Specifications	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Runs on Windows NT	2	1	2	2
Regular on-screen status notification	3	1	3	3
Can record patterns in user-software interactions	2	1	2	2
Minimum required processor speed of 100 MHz	2	1	2	2
Minimum required memory 24 MB	2	0	2	0
Minimum required hard disk space of 100 MB	2	0	2	0
Ability to set alarm points based on device/user inputs	2	1	2	2
Support of different Levels of Security Access	3	1	3	3
SCORE			**18**	**14**

Table B-33. Performance Form for OI System at Locks No. 27.

Detailed Performance Score for OI PC at Locs No. 27 visited 26 May 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score				
How would your rate the technical support	2	2	4	4
PC Components Score: ICS (same as Melvin Price Locks and Dam)				
How would you rate the dependability of the self-diagnosics messages	3	2	6	6
How would you rate the pc's tendency to crash	3	2	6	6
Monitor Score: Acer				
How would you rate the monitor's resistance to glare	3	0	6	0
How would you rate the visibility of the icons and menus on the monitor	3	0	6	0
How would you rate the "fit" of the monitor in the control room	1	2	2	2
Design Score				
How would you rate the PC's capacity to accommodate more peripheral cards	1	1	2	1
How would you rate the PC's built-in batter back-up	2	2	4	4
How would your rate the fit of the PC in the control room	1	2	2	2
How would you rate the PC's lightning/surge protection	2	2	4	4
SCORE			**42**	**29**

Detailed Performance Score for OI software running at Locks No. 27 visited 26 May 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
How would you rate the difficulty of learning to use the OI	3	2	6	6
How would you rate the clarity of the icons and menus of the OI	3	2	6	6
How would you rate the use of display space on the GUI	2	2	4	4
How would you rate the way that changes in ladder logic are integated into the OI	1	2	2	2
How would you rate the OI's usefulness in locating faults detected by the sensors	3	2	6	6
SCORE			**24**	**24**

Table B-34. Specifications Form for OI System at Winfield Locks.

Detailed Specifications Score for OI PC at Winfield Lock visited 4 June 1999				
Listed Specifications	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score				
PC production for 10 years	3	1	6	6
PC Components Score: IBM				
120 MHz processor	1	2	2	2
64 MB RAM	1	1	2	1
365 MB Hard Drive	1	2	2	2
Ethernet and serial communications ports	1	1	1	1
Windows NT Operating System	3	1	3	3
Monitor Score: NEC multisync XE21 (JC-2131VMA)				
30 MHz video bandwidth	3	2	6	6
60 Hz Vertical Scan Frequency	1	2	2	2
800X600 Pixel Maximum Resolution	1	2	2	2
70 Hz Horizontal Scan Frequency	1	2	2	2
Energy Star and VESA compliance	3	2	6	6
5-year Warranty	3	0	6	0
Chassis Score: IBM				
Passive Backplane	2	1	2	2
Rack Mountable	2	1	2	2
2 or More Fans in Cooling System	1	1	1	1
Dust Filtering system	1	1	1	1
Metal chassis	1	1	1	1
SCORE			**47**	**40**

Detailed Specifications Score for OI Software at Winfield Lock Visited 4 June 1999				
Listed Specifications	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Runs on Windows NT	2	1	2	2
Regular on-screen status notification	3	1	3	3
Can record patterns in user-software interactions	2	1	2	2
Minimum required processor speed of 100 MHz	2	1	2	2
Minimum required memory 24 MB	2	1	2	2
Minimum required hard disk space of 100 MB	2	1	2	2
Ability to set alarm points based on device/user inputs	2	1	2	2
Support of different Levels of Security Access	3	1	3	3
SCORE			**18**	**18**

Table B-35. Performance Form for OI System at Winfield Locks.

Detailed Performance for OI PC at Winfield Lock visited 4 June 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score				
How would your rate the technical support	2	2	4	4
PC Components Score: IBM				
How would you rate the dependability of the self-diagnosics messages	3	2	6	6
How would you rate the pc's tendency to crash	3	2	6	6
Monitor Score: NEC multisync XE21 (JC-2131VMA)				
How would you rate the monitor's resistance to glare	3	2	6	6
How would you rate the visibility of the icons and menus on the monitor	3	2	6	6
How would you rate the "fit" of the monitor in the control room	1	2	2	2
Design Score				
How would you rate the PC's capacity to accommodate more peripheral cards	1	2	2	2
How would you rate the PC's built-in batter back-up	2	2	4	4
How would your rate the fit of the PC in the control room	1	2	2	2
How would you rate the PC's lightning/surge protection	2	2	4	4
SCORE			**42**	**42**

Detailed Performance Score for OI Software at Winfield Lock visited 4 June 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
How would you rate the difficulty of learning to use the OI	3	2	6	6
How would you rate the clarity of the icons and menus of the OI	3	2	6	6
How would you rate the use of display space on the GUI	2	2	4	4
How would you rate the way that changes in ladder logic are integated into the OI	1	2	2	2
How would you rate the OI's usefulness in locating faults detected by the sensors	3	2	6	6
SCORE			**24**	**24**

Table B-36. Performance Forms for OI System at Wilson (main) Lock.

Detailed Peformance score for OI hardware at Wilson (main) Lock and Dam visited 21 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score				
How would your rate the technical support	2	2	4	4
PC Components Score: CTC				
How would you rate the dependability of the self-diagnosics messages	3	2	6	6
How would you rate the pc's tendency to crash	3	2	6	6
Monitor Score: CTC				
How would you rate the monitor's resistance to glare	3	1	6	3
How would you rate the visibility of the icons and menus on the monitor	3	1	6	3
How would you rate the "fit" of the monitor in the control room	1	1	2	1
Design Score				
How would you rate the PC's capacity to accommodate more peripheral cards	1	0	2	0
How would you rate the PC's built-in batter back-up	2	2	4	4
How would your rate the fit of the PC in the control room	1	1	2	1
How would you rate the PC's lightning/surge protection	2	2	4	4
SCORE			42	32

Detailed Performance Score for OI Software at Wilson (main) Lock and Dam visited 21 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
How would you rate the difficulty of learning to use the OI	3	2	6	6
How would you rate the clarity of the icons and menus of the OI	3	2	6	6
How would you rate the use of display space on the GUI	2	2	4	4
How would you rate the way that changes in ladder logic are integated into the OI	1	1	2	1
How would you rate the OI's usefulness in locating faults detected by the sensors	3	2	6	6
SCORE			24	23

Table B-37. Performance Form for OI System at Barkley Lock.

Panel Mate minimal hardwired backup support GUI at Barkley Dam and Lake Barkley visited 18 February 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
How would you rate the difficulty of learning to use the MMI	3	2	6	6
How would you rate the clarity of the icons and menus of the MMI	3	2	6	6
How would you rate the use of display space on the user interface	2	2	4	4
How would you rate the way that changes in ladder logic are integated into the MMI	1	2	2	2
How would you rate the MMI's usefulness in locating faults detected by the sensors	3	1	6	3
SCORE			24	21

Pushbutton Control

Table B-38. Performance Forms for OI Systems at Calcasieu Lock, Leland-Bowman Lock, Bonneville Lock, and Lock 1.

Detailed performance score for pushbutton control panel at Calcasieu Lock visited 16 March 1999				
Evaluation Criteria	**Weight**	**Raw score**	**Max Score**	**Real Score**
How would you rate the difficulty of learning to use the OI	3	2	6	6
How would you rate the clarity of the icons and menus of the OI	3	2	6	6
How would you rate the use of display space on the user interface	2	2	4	4
How would you rate the way that changes in ladder logic are integated into the OI	1	2	2	2
How would you rate the OI's usefulness in locating faults detected by the sensors	3	0	6	0
SCORE			**24**	**18**

Detailed performance score for pushbutton control panel at Leland-Bowman Lock visited 15 March 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
How would you rate the difficulty of learning to use the OI	3	2	6	6
How would you rate the clarity of the icons and menus of the OI	3	2	6	6
How would you rate the use of display space on the user interface	2	2	4	4
How would you rate the way that changes in ladder logic are integated into the OI	1	2	2	2
How would you rate the OI's usefulness in locating faults detected by the sensors	3	0	6	0
SCORE			**24**	**18**

Detailed performance score for pushbutton control panel at Bonneville Lock and Dam visited 1 March 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
How would you rate the difficulty of learning to use the OI	3	2	6	6
How would you rate the clarity of the icons and menus of the OI	3	2	6	6
How would you rate the use of display space on the user interface	2	2	4	4
How would you rate the way that changes in ladder logic are integated into the OI	1	2	2	2
How would you rate the OI's usefulness in locating faults detected by the sensors	3	0	6	0
SCORE			**24**	**18**

Detailed performance soccer for pushbutton control panel at Lock 1 (St. Paul, MN) visited 2 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
How would you rate the difficulty of learning to use the OI	3	2	6	6
How would you rate the clarity of the icons and menus of the OI	3	2	6	6
How would you rate the use of display space on the user interface	2	2	4	4
How would you rate the way that changes in ladder logic are integated into the OI	1	2	2	2
How would you rate the OI's usefulness in locating faults detected by the sensors	3	0	6	0
SCORE			**24**	**18**

Table B-39. Performance Form for OI at Lockport Lock.

Detailed performance score for OI at Lockport Lock visited 16 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
How would you rate the difficulty of learning to use the OI	3	2	6	6
How would you rate the clarity of the icons and menus of the OI	3	2	6	6
How would you rate the use of display space on the user interface	2	2	4	4
How would you rate the way that changes in ladder logic are integated into the OI	1	2	2	2
How would you rate the OI's usefulness in locating faults detected by the sensors	3	0	6	0
SCORE			**24**	**18**

Table B-40. Performance Forms for Pickwick, Wheeler, and Port St. Lucie Locks.

Detailed performance score for OI at Pickwick Lock visited 21 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
How would you rate the difficulty of learning to use the OI	3	2	6	6
How would you rate the clarity of the icons and menus of the OI	3	2	6	6
How would you rate the use of display space on the user interface	2	2	4	4
How would you rate the way that changes in ladder logic are integated into the OI	1	2	2	2
How would you rate the OI's usefulness in locating faults detected by the sensors	3	0	6	0
SCORE			**24**	**18**

Detailed performance score for OI at General Joe Wheeler Lock and Dam visited 22 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
How would you rate the difficulty of learning to use the OI	3	2	6	6
How would you rate the clarity of the icons and menus of the OI	3	2	6	6
How would you rate the use of display space on the user interface	2	2	4	4
How would you rate the way that changes in ladder logic are integated into the OI	1	2	2	2
How would you rate the OI's usefulness in locating faults detected by the sensors	3	0	6	0
SCORE			**24**	**18**

Detailed performance score for OI at Port St. Lucie Lock visited Feb 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
How would you rate the difficulty of learning to use the OI	3	2	6	6
How would you rate the clarity of the icons and menus of the OI	3	2	6	6
How would you rate the use of display space on the user interface	2	2	4	4
How would you rate the way that changes in ladder logic are integated into the OI	1	1	2	1
How would you rate the OI's usefulness in locating faults detected by the sensors	3	0	6	0
SCORE			**24**	**17**

CCTV Systems

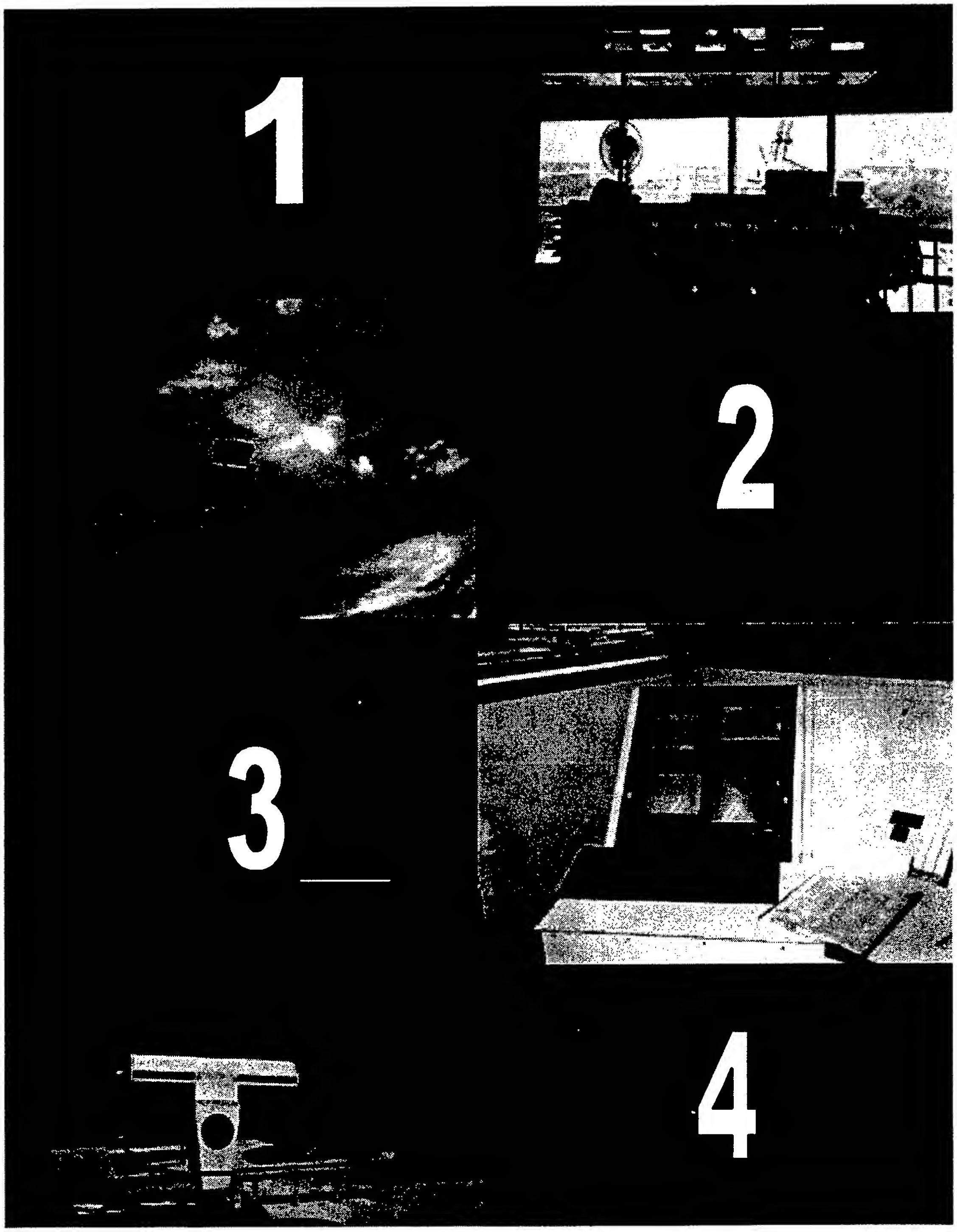


Figure B-3. Components of CCTV Systems: (1) Central control room with CCTV monitors and GUI control screens, (2) CCTV camera, (3) CCTV monitors and display control, (4) CCTV camera.

In most cases, the closed-circuit television (CCTV) system is used to enhance visibility for lock personnel. Some examples of CCTV system cameras and monitors are shown in Figure 3. At those locks with especially high normal lifts, the CCTV System is a safety necessity. In many cases, those locks have water discharge areas that the lock operator can not easily see from the control room. Serious damage to property and injuries could occur if a recreational craft were in the vicinity of the discharge area when the lock chamber is being emptied. At those locks with heavy traffic at all hours of the day and night, the CCTV cameras provide for a higher level of accountability and record keeping in the event of an accident. At some locks the CCTV systems also serve to secure the grounds of the lock.

The components of the CCTV systems that are the most vital are the cameras, monitors, and communications network. In developing the specification and evaluation forms for the CCTV systems, focus was placed on these parts.

Cameras come with a myriad of options and functions including, but not limited to, the following:

- Color or monochrome
- Pick-up type
- Anti-blooming capability
- Fixed or zoom lenses
- Auto light adjustment capability
- Fiber optic video feedback
- Surge protection

In addition to the options and functions that come with a camera, certain design issues come into play when the CCTV system is to be used as part of the controls at a lock.

These issues are presented below in the form of questions about the system:

- Is the camera control handled through the same communications lines as the video?

- What kind of camera control mechanism does the system employ?
- Does the system incorporate switcher partitioning capabilities?
- Are the cameras environmentally resistant?
- What kind of lightning/surge protection do the cameras, receivers and other equipment have?
- Does the camera system have remote (offsite) monitoring/control capabilities?

The specification evaluation forms seek to isolate the components of the CCTV system that address as many of these specific issues as possible. The performance evaluation forms again are intended to reflect the experiences of the operators with their particular CCTV system. The Evaluation Forms for the CCTV systems are presented in Tables B-41 through B-48.

Nashville District

Table B-41. Evaluation Forms for CCTV System at Barkley Lock.

Detailed Performance Score for CCTV System at Barkley Lock visited 2 August 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score				
How would your rate the technical support	2	1	4	2
How would your rate the access to spare parts	3	0	6	0
How would you rate the compatibility of new replacements for old parts	3	0	6	0
Camera Score: Phillips TC0500/60 Monochrome CCD Cameras				
How would you rate the dependability of the system's self diagnostics	2	1	4	2
How would you rate the reliability of the cameras	3	1	6	3
How would you rate the camera's effectiveness during day and night use	2	1	4	2
Monitor Score: Phillips LTC2009/61 9" Monitor				
How would you rate the tv screen's resistance to glare	2	1	4	2
How would you rate the visibility of objects on the screen	2	1	4	2
How would you rate the tv monitor's "fit" in the control room	1	2	2	2
Design Score				
How would you rate the suitability of the system for the lock environment	2	2	4	4
How would you rate the camera positioning	2	2	4	4
How would you rate system's surge/lightning protection	1	1	2	1
SCORE			50	24

Detailed Specifications Score for CCTV System at Barkley Lock visited 2 August 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score				
Has been producing CCTV systems in excess of 10 years	2	1	2	2
Has product distributor within 50 miles of the lock	3	1	3	3
Camera Score: Phillips TC0500/60 Monochrome CCD Cameras				
Resolution: 580 lines (B&W) or 460 lines (color)	1	0	2	0
Sensitivity(at minimum usable picture): 0.02 lux (B&W) or 0.08 lux (color)	2	2	4	4
S/N Ratio: 55 dB (B&W) or 48 dB (color)	2	0	4	0
6x optical zoom	1	1	2	1
Monitor Score: Phillips LTC2009/61 9" Monitor				
Resolution: 1000 lines (center) and 800 lines (corner)	2	0	4	0
UL listed to standard 1419, CE compliant, Compliant to CSA Standard C22.2	3	0	6	0
Operating Temperature: 14 to 122 degrees Fahrenheit	1	1	2	1
Humidity resistant to 90% relative, noncondensing	3	1	6	3
Rack mountable	2	1	2	2
Enclosure Score: Burle TC9340A				
CE compliant, NEMA 4 Rating, IP66 certified	3	1	3	3
Operating Temperature: -40 to 60 degrees Celsius	3	0	6	0
Protects in 100% humidity	3	1	3	3
Fiber Optic Video Output	1	1	1	1
sunshield	1	1	1	1
wipers/washers	1	0	1	0
Internal heater and low pressure sensor	1	0	1	0
shock resistant to 15 g, 11 ms	1	1	2	1
SCORE			55	25

Table B-42. Evaluation Forms for CCTV System at Wheeler Lock.

Detailed Performance Score for CCTV System at Wheeler Lock visited 22 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer: Phillips				
How would your rate the technical support	2	1	4	2
How would your rate the access to spare parts	3	1	6	3
How would you rate the compatibility of new replacements for old parts	3	1	6	3
Camera: Phillips TC0500/60 Monochrome CCD Cameras				
How would you rate the dependability of the system's self diagnostics	2	1	4	2
How would you rate the reliability of the cameras	3	1	6	3
How would you rate the camera's effectiveness during day and night use	2	1	4	2
Monitor: Phillips LTC2009/61 9" Monitor				
How would you rate the tv screen's resistance to glare	2	1	4	2
How would you rate the visibility of objects on the screen	2	1	4	2
How would you rate the tv monitor's "fit" in the control room	1	1	2	1
Design				
How would you rate the suitability of the system for the lock environment	2	1	4	2
How would you rate the camera positioning	2	1	4	2
How would you rate system's surge/lightning protection	1	1	2	1
SCORE			50	25

Detailed Specifications Score for CCTV System at Wheeler Lock visited 22 June 1999				
Listed Specifications	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer: Phillips				
Has been producing CCTV systems in excess of 10 years	2	1	2	2
Has product distributor within 50 miles of the lock	3	1	3	3
Camera: Phillips TC0500/60 Monochrome CCD Cameras				
Resolution: 580 lines (B&W) or 460 lines (color)	1	0	2	0
Sensitivity(at minimum usable picture): 0.02 lux (B&W) or 0.08 lux (color)	2	2	4	4
S/N Ratio: 55 dB (B&W) or 48 dB (color)	2	0	4	0
6x optical zoom	1	1	2	1
Monitor: Phillips LTC2009/61 9" Monitor				
Resolution: 1000 lines (center) and 800 lines (corner)	2	0	4	0
UL listed to standard 1419, CE compliant, Compliant to CSA Standard C22.2	3	0	6	0
Operating Temperature: 14 to 122 degrees Fahrenheit	1	1	2	1
Humidity resistant to 90% relative, noncondensing	3	1	6	3
Rack mountable	2	1	2	2
Enclosure: Burle TC9340A				
CE compliant, NEMA 4 Rating, IP66 certified	3	1	3	3
Operating Temperature: -40 to 60 degrees Celsius	3	0	6	0
Protects in 100% humidity	3	1	3	3
Fiber Optic Video Output	1	1	1	1
sunshield	1	1	1	1
wipers/washers	1	0	1	0
Internal heater and low pressure sensor	1	0	1	0
shock resistant to 15 g, 11 rms	1	1	2	1
SCORE			55	25

Table B-43. Evaluation Forms for CCTV System at Pickwick Lock.

Detailed Performance Score for CCTV System at Pickwick Lock visited 21 June 1999				
Evaulation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer: Phillips				
How would your rate the technical support	2	2	4	4
How would your rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Camera: Phillips TC0500/60 Monochrome CCD Cameras				
How would you rate the dependability of the system's self diagnostics	2	2	4	4
How would you rate the reliability of the cameras	3	2	6	6
How would you rate the camera's effectiveness during day and night use	2	1	4	2
Monitor: Phillips LTC2009/61 9" Monitor				
How would you rate the tv screen's resistance to glare	2	1	4	2
How would you rate the visibility of objects on the screen	2	2	4	4
How would you rate the tv monitor's "fit" in the control room	1	2	2	2
Design				
How would you rate the suitability of the system for the lock environment	2	2	4	4
How would you rate the camera positioning	2	2	4	4
How would you rate system's surge/lightning protection	1	2	2	2
SCORE			50	46

Detailed Specifications Score for CCTV System at Pickwick Lock visited 21 June 1999				
Listed Specifications	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer: Phillips				
Has been producing CCTV systems in excess of 10 years	2	1	2	2
Has product distributor within 50 miles of the lock	3	1	3	3
Camera: Phillips TC0500/60 Monochrome CCD Cameras				
Resolution: 580 lines (B&W) or 460 lines (color)	1	0	2	0
Sensitivity: 0.02 lux (B&W) or 0.08 lux (color)	2	2	4	4
S/N Ratio: 55 dB (B&W) or 48 dB (color)	2	0	4	0
6x optical zoom	1	1	2	1
Monitor: Phillips LTC2009/61 9" Monitor				
Resolution: 1000 lines (center) and 800 lines (corner)	2	0	4	0
UL listed to standard 1419, CE compliant, Compliant to CSA Standard C22.2	3	0	6	0
Operating Temperature: 14 to 122 degrees Fahrenheit	1	1	2	1
Humidity resistant to 90% relative, noncondensing	3	1	6	3
Rack mountable	2	1	2	2
Enclosure: Burle TC9340A				
CE compliant, NEMA 4 Rating, IP66 certified	3	1	3	3
Operating Temperature: -40 to 60 degrees Celsius	3	0	6	0
Protects in 100% humidity	3	1	3	3
Fiber Optic Video Output	1	1	1	1
sunshield	1	1	1	1
wipers/washers	1	0	1	0
Internal heater and low pressure sensor	1	0	1	0
shock resistant to 15 g, 11 rms	1	1	2	1
SCORE			55	25

St. Louis District

Table B-44. Evaluation Forms for CCTV System at Lock No. 24.

Detailed Performance Score for CCTV System at Lock 24 visited 26 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer: Various Industry Leaders				
How would your rate the technical support	2	2	4	4
How would your rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Camera: Panasonic WV-BP310 Series Black and White CCD Camera				
How would you rate the dependability of the system's self diagnostics	2	2	4	4
How would you rate the reliability of the cameras	3	2	6	6
How would you rate the camera's effectiveness during day and night use	2	2	4	4
Monitor: Sony SSM171 17" Black and White Monitor				
How would you rate the tv screen's resistance to glare	2	1	4	2
How would you rate the visibility of objects on the screen	2	1	4	2
How would you rate the tv monitor's "fit" in the control room	1	2	2	2
Design				
How would you rate the suitability of the system for the lock environment	2	1	4	2
How would you rate the camera positioning	2	2	4	4
How would you rate system's surge/lightning protection	1	2	2	2
SCORE			50	44

Detailed Specifications Score for CCTV System at Lock 24 visited 26 May 1999				
Listed Specifications	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer: Various Industry Leaders				
Has been producing CCTV systems in excess of 10 years	2	1	4	2
Has product distributor within 50 miles of the lock	3	1	3	3
Camera: Panasonic WV-BP310 Series Black and White CCD Camera				
Resolution: 580 lines (B&W) or 460 lines (color)	1	0	2	0
Sensitivity(at minimum usable picture): 0.02 lux (B&W) or 0.08 lux (color)	2	0	4	0
S/N Ratio: 55 dB (B&W) or 48 dB (color)	2	0	4	0
6x optical zoom	1	1	2	1
Monitor : Sony SSM171 17" Black and White Monitor				
Resolution: 1000 lines (center) and 800 lines (corner)	2	2	4	4
UL listed to standard 1419, CE compliant, Compliant to CSA Standard C22.2	1	0	2	0
Operating Temperature: 14 to 122 degrees Fahrenheit	3	2	6	6
Humidity resistant to 90% relative, noncondensing	3	0	1	0
Rack mountable	2	1	2	2
Enclosure: Pelco (no model or specifications information available)				
CE compliant, NEMA 4 Rating, IP66 certified	3	0	6	0
Operating Temperature: -40 to 60 degrees Celsius	3	0	6	0
Protects in 100% humidity	3	0	3	0
Fiber Optic Video Output	1	0	1	0
sunshield	1	0	1	0
wipers/washers	1	0	1	0
Internal heater and low pressure sensor	1	0	1	0
shock resistant to 15 g, 11 ms	1	0	2	0
SCORE			55	18

Table B-45. Evaluation Forms for CCTV System at Melvin Price Locks.

Detailed Performance Score for CCTV System at Melvin Price Locks and Dam visited 25 May 1999						
Evaluation Criteria	**Weight**	**Raw Score**		**Max Score**	**Real Score**	
Manufacture: Vicon						
How would your rate the technical support	2	2		4	4	
How would your rate the access to spare parts	3	2		6	6	
How would you rate the compatibility of new replacements for old parts	3	2		6	6	
Camera :Vicon VC2820A-24						
How would you rate the dependability of the system's self diagnostics	2	2		4	4	
How would you rate the reliability of the cameras	3	2		6	6	
How would you rate the camera's effectiveness during day and night use	2	2		4	4	
Monitor : Vicon Model #VM6092 9" Color Monitor & Vicon Model #VM5093 9" B&W Monitor		color	b&w		color	b&w
How would you rate the tv screen's resistance to glare	2	1	1	4	2	2
How would you rate the visibility of objects on the screen	2	1	2	4	2	4
How would you rate the tv monitor's "fit" in the control room	1	2	2	2	2	2
Design						
How would you rate the suitability of the system for the lock environment	2	2		4	4	
How would you rate the camera positioning	2	2		4	4	
How would you rate system's surge/lightning protection	1	2		2	2	
SCORE				**50**	**46**	**48**

Detailed Specifications Score for CCTV System at Melvin Price Locks and Dam visited 25 May 1999						
Listed Specifications	**Weight**	**Raw Score**		**Max Score**	**Real Score**	
Manufacturer: Vicon						
Has been producing CCTV systems in excess of 10 years	2	1		2	2	
Has product distributor within 50 miles of the lock	3	1		3	3	
Camera: Vicon VC2820A-24						
Resolution: 580 lines (B&W) or 460 lines (color)	1	1		2	1	
Sensitivity(at minimum usable picture): 0.02 lux (B&W) or 0.08 lux (color)	2	0		4	0	
S/N Ratio: 55 dB (B&W) or 48 dB (color)	2	2		4	4	
6x optical zoom	1	1		2	1	
Monitor: Vicon Model #VM6092 9" Color Monitor & Vicon Model #VM5093 9" B&W Monitor		color	b&w		color	b&w
Resolution: 1000 lines (center) and 800 lines (corner)	2	0	1	4	0	2
UL listed to standard 1419, CE compliant, Compliant to CSA Standard C22.2	1	0	0	2	0	0
Operating Temperature: 14 to 122 degrees Fahrenheit	3	0	1	6	0	3
Humidity resistant to 90% relative, noncondensing	3	0	0	3	0	0
Rack mountable	2	1	1	2	2	2
Camera Enclosure: Vicon Industries V8650H-24						
CE compliant, NEMA 4 Rating, IP66 certified	3	1		6	3	
Operating Temperature: -40 to 60 degrees Celsius	3	2		6	6	
Protects in 100% humidity	3	1		3	3	
Fiber Optic Video Output	1	0		1	0	
sunshield	1	0		1	0	
wipers/washers	1	0		1	0	
Internal heater and low pressure sensor	1	1		1	1	
shock resistant to 15 g, 11 rms	1	1		2	1	
SCORE				**55**	**27**	**32**

Huntington District

Table B-46. Evaluation Forms for CCTV System at Winfield Lock.

Detailed Performance Score for CCTV System at Winfield Lock visited 4 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer: Burle				
How would your rate the technical support	2	1	4	2
How would your rate the access to spare parts	3	1	6	3
How would you rate the compatibility of new replacements for old parts	3	1	6	3
Camera: Burle TC351A				
How would you rate the dependability of the system's self diagnostics	2	1	4	2
How would you rate the reliability of the cameras	3	1	6	3
How would you rate the camera's effectiveness during day and night use	2	1	4	2
Monitor: Burle TC1917				
How would you rate the tv screen's resistance to glare	2	1	4	2
How would you rate the visibility of objects on the screen	2	1	4	2
How would you rate the tv monitor's "fit" in the control room	1	1	2	1
Design				
How would you rate the suitability of the system for the lock environment	2	1	4	2
How would you rate the camera positioning	2	1	4	2
How would you rate system's surge/lightning protection	1	1	2	1
SCORE			50	25

Detailed Specifications Score for CCTV System at Winfield Lock visited 4 June 1999				
Listed Specifications	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer: Burle				
Has been producing CCTV systems in excess of 10 years	2	1	2	2
Has product distributor within 50 miles of the lock	3	0	3	0
Camera : Phillips (Burle) LTC351A				
Resolution: 580 lines (B&W) or 460 lines (color)	1	0	2	0
Sensitivity(at minimum usable picture): 0.02 lux (B&W) or 0.08 lux (color)	2	2	4	4
S/N Ratio: 55 dB (B&W) or 48 dB (color)	2	2	4	4
6x optical zoom	1	1	2	1
Monitor: Phillips (Burle) LTC1917				
Resolution: 1000 lines (center) and 800 lines (corner)	2	0	4	0
UL listed to standard 1419, CE compliant, Compliant to CSA Standard C22.2	1	1	2	1
Operating Temperature: 14 to 122 degrees Fahrenheit	3	1	6	3
Humidity resistant to 90% relative, noncondensing	3	1	6	3
Rack mountable	2	1	2	2
Enclosure: Phillips (Burle) TC9340A				
CE compliant, NEMA 4 Rating, IP66 certified	3	0	3	0
Operating Temperature: -40 to 60 degrees Celsius	3	0	6	0
Protects in 100% humidity	3	0	3	0
Fiber Optic Video Output	1	0	1	0
sunshield	1	1	1	1
wipers/washers	1	0	1	0
Internal heater and low pressure sensor	1	1	1	1
shock resistant to 15 g, 11 rms	1	1	2	1
SCORE			55	23

Portland District

Table B-47. Evaluation Forms for CCTV System at Bonneville Lock.

Detailed Specifications Score for CCTV system at Bonneville Lock and Dam visited 1 March 1999				
Listed Specifications	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer: Burle (Philips)				
Has been producing CCTV systems in excess of 10 years	2	1	2	2
Has product distributor within 50 miles of the lock	3	1	3	3
Camera: Burle TC652				
Resolution: 580 lines (B&W) or 460 lines (color)	1	1	2	1
Sensitivity(at minimum usable picture): 0.02 lux (B&W) or 0.08 lux (color)	2	1	4	2
S/N Ratio: 55 dB (B&W) or 48 dB (color)	2	1	4	2
6x optical zoom	1	1	2	1
Monitor: Burle TC1910				
Resolution: 1000 lines (center) and 800 lines (corner)	2	1	4	2
UL listed to standard 1419, CE compliant, Compliant to CSA Standard C22.2	1	1	2	1
Operating Temperature: 14 to 122 degrees Fahrenheit	3	1	6	3
Humidity resistant to 90% relative, noncondensing	3	1	6	3
Rack mountable	2	1	2	2
Enclosure: Burle TC9340				
CE compliant, NEMA 4 Rating, IP66 certified	3	1	3	3
Operating Temperature: -40 to 60 degrees Celsius	3	1	6	3
Protects in 100% humidity	3	1	3	3
Fiber Optic Video Output	1	1	1	1
sunshield	1	1	1	1
wipers/washers	1	0	1	0
Internal heater and low pressure sensor	1	0	1	0
shock resistant to 15 g, 11 rms	1	1	2	1
SCORE			55	34

Detailed performance score for CCTV system at Bonneville Lock and Dam visited 1 March 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer: Burle				
How would your rate the technical support	2	2	4	4
How would your rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Camera: TC652				
How would you rate the dependability of the system's self diagnostics	2	2	4	4
How would you rate the reliability of the cameras	3	2	6	6
How would you rate the camera's effectiveness during day and night use	2	2	4	4
Monitor: TC1910				
How would you rate the tv screen's resistance to glare	2	1	4	2
How would you rate the visibility of objects on the screen	2	1	4	2
How would you rate the tv monitor's "fit" in the control room	1	1	2	1
Design				
How would you rate the suitability of the system for the lock environment	2	2	4	4
How would you rate the camera positioning	2	2	4	4
How would you rate system's surge/lightning protection	1	2	2	2
SCORE			50	45

Jacksonville District

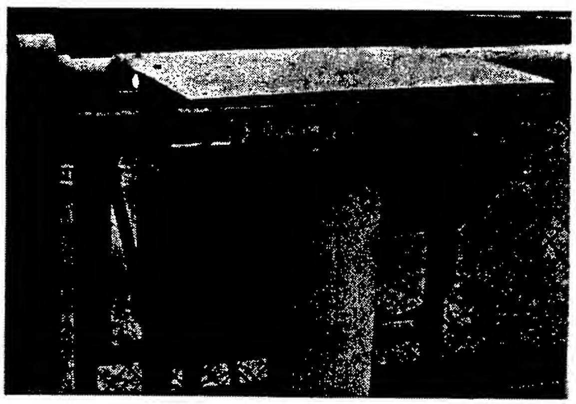
Table B-48. Evaluation Forms for CCTV System at Port St. Lucie Lock.

Detailed Specifications Score for CCTV system at Port St. Lucie Lock visited February 1999				
Listed Specifications	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer: Philips				
Has been producing CCTV systems in excess of 10 years	2	1	2	2
Has product distributor within 50 miles of the lock	3	1	3	3
Camera: Philips VCM 1152/007				
Resolution: 580 lines (B&W) or 460 lines (color)	1	1	2	1
Sensitivity(at minimum usable picture): 0.02 lux (B&W) or 0.08 lux (color)	2	1	4	2
S/N Ratio: 55 dB (B&W) or 48 dB (color)	2	1	4	2
6x optical zoom	1	2	2	2
Monitor: Philips VS82505T				
Resolution: 1000 lines (center) and 800 lines (corner)	2	1	4	2
UL listed to standard 1419, CE compliant, Compliant to CSA Standard C22.2	1	1	2	1
Operating Temperature: 14 to 122 degrees Fahrenheit	3	1	6	3
Humidity resistant to 90% relative, noncondensing	3	1	6	3
Rack mountable	2	1	2	2
Enclosure: No Information Available				
CE compliant, NEMA 4 Rating, IP66 certified	3	0	3	0
Operating Temperature: -40 to 60 degrees Celsius	3	0	6	0
Protects in 100% humidity	3	0	3	0
Fiber Optic Video Output	1	0	1	0
sunshield	1	0	1	0
wipers/washers	1	0	1	0
Internal heater and low pressure sensor	1	0	1	0
shock resistant to 15 g, 11 rms	1	0	2	0
SCORE			**55**	**23**

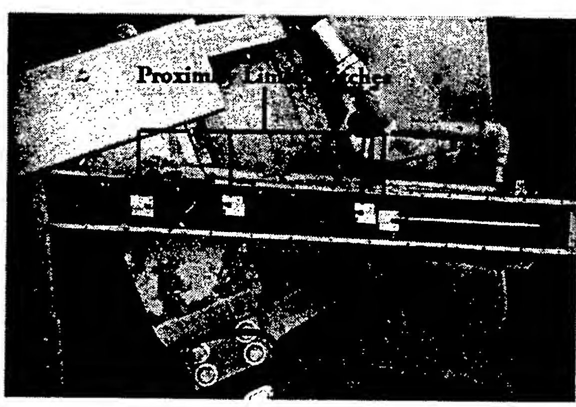
Detailed performance score for CCTV system at Port St. Lucie Lock visited February 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer: Phillips				
How would your rate the technical support	2	2	4	4
How would your rate the access to spare parts	3	1	6	3
How would you rate the compatibility of new replacements for old parts	3	1	6	3
Camera: Philips VCM 1152/007				
How would you rate the dependability of the system's self diagnostics	2	1	4	2
How would you rate the reliability of the cameras	3	2	6	6
How would you rate the camera's effectiveness during day and night use	2	1	4	2
Monitor: Philips VS82505T				
How would you rate the tv screen's resistance to glare	2	1	4	2
How would you rate the visibility of objects on the screen	2	1	4	2
How would you rate the tv monitor's "fit" in the control room	1	1	2	1
Design				
How would you rate the suitability of the system for the lock environment	2	1	4	2
How would you rate the camera positioning	2	1	4	2
How would you rate system's surge/lightning protection	1	2	2	2
SCORE			**50**	**31**

d. Sensors & Switches

Lock that uses lever-arm limit switches that make physical contact with moving parts to indicate gate position



Lock that uses rotary position transmitter and selsyn to indicate gate position



Lock that uses magnetic proximity switches along the path of the gate drive arm to indicate gate position

Figure B-4. Various Position Sensor Configurations.

The locks use a wide variety of devices to indicate machinery position: magnetic vane switches, proximity switches, traveling nut limit switches, lever-arm limit switches, position encoders, position resolvers, and rotary position transmitters. Several examples of position sensors are shown in Figure 4. These instruments not only have distinct specifications due to the differences in the way they operate, but manufacturers also provide specifications for devices based on the functions that they perform. For instance, some locks use lever-arm limit switches strictly for overtravel indication while others integrate these switches into their position indication scheme. For these reasons, the switches and sensors are not evaluated individually but the performance of the functions in which they are employed have been surveyed.

Moreover, specification evaluations are not provided for the sensors and switches because no common set of specifications or options could be identified for all the different kinds of switches.

These status-monitoring schemes are tied into the PLC system to provide feedback to the operators and maintenance staff. The degree of status feedback provided by the sensors and switches varied from lock to lock. However, many of the locks surveyed for this report have some means of indicating gate and valve position, as well as pool level. These systems are evaluated in this section, and the evaluation forms are presented in Tables B-49 through B-67.

Lock Gate Position Indicators

At most locks, the position of the gates during their travel from open to closed is indicated by a series of limit switches positioned along the path of motion of the gate machinery. These mechanical switches are available as either "normally open" or "normally closed." As the lock machinery moves the gate, a physical contact on the switch is made. Once the switch is triggered, it sends a discrete opened/closed signal to the PLC system. This type of position indication is very reliable and accurate as long as the limit switches function properly. However, at very busy locks the constant physical movement and contact of the switches cause them to fail. To overcome this, many locks have started using proximity switches to replace the mechanical switches. These switches have the added advantage of not making contact with the operating machinery. Another type of position indication device is the rotating shaft position transmitter. This device attaches directly to the motor operating a gate. As the motor rotates, it sends an analog signal to the PLC system indicating exactly how much the machinery has rotated. The PLC is then programmed to calculate the distance the gate has traveled from this information. The last type of position indication device encountered in this study is the rotating encoder. It performs much the same as

the rotating shaft position transmitter except that it has fewer moving parts and is less likely to fail as a result of wear. The lock gate position indicators evaluation forms are presented as Tables B-49 through B-66.

Table B-49. Performance Form for Lift Gate Position Indicator at Melvin Price Locks.

Detailed performance score for lift gate position indicator at Melvin Price Locks and Dam visited 25 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Astrostystems, Inc. DuraPot HDC40 PT rotating shaft position transmitter				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	56

Table B-50. Performance Form for Miter Gate Position Indicator at Lock No. 24.

Detailed performance score for miter gate position indicator at Lock No. 24 visited 26 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Astrosystems, Inc. DuraPot HDC40 rotating shaft position transmitter				
How would you rate the technical support	1	2	2	2
How would you rate the access ro spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	56

Table B-51. Performance Form for Miter Gate Position Indicator at Melvin Price Locks.

Detailed performance score for miter gate position indicator at Melvin Price Locks and Dam visited 25 May 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Cutler Hammer E51ALT16PU Form C limit switch				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	56

Table B-52. Performance Form for Miter Gate Position Indicator at Lock No. 25.

Detailed performance for miter gate position indicator at Lock No. 25 visited 26 May 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Astrosystems, Inc. DuraPot HDC 40 PT rotating shaft position transmitter				
How would you rate the technical support	1	1	2	1
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	55

Table B-53. Performance Form for Miter Gate Position Indicator at Locks No. 27.

Detailed performance score for miter gate position indicator at Locks No. 27 visited 26 May 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Rexroth Ceramax Integrated Measurement System (CIMS)				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	56

Table B-54. Performance Form for Miter Gate Position Indicator at Pickwick Lock.

Detailed performance score for miter gate position indicator at Pickwick Landing Lock and Dam (visited 21 June 1999)				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Calibrated gearbox mechanism				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	1	6	3
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	1	4	2
SCORE			56	49

Table B-55. Performance Form for Miter Gate Position Indicator at Barkley Lock.

Detailed performance score for miter gate position indicator at Barkley Dam, Lake Barkley (visited 2 August 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Proximity Controls Rotary Position Tramsnmitter and Switch Model #35AD1				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			**56**	**56**

Table B-56. Performance Form for Miter Gate Position Indicator at Wilson (main) Lock.

Detailed performance score for miter gate position indicator at Wilson (main) lock (visited 21 June 1999)				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: BRX FA-Solver Type 800123-R resolver				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			**56**	**56**

Table B-57. Performance Form for Miter Gate Position Indicator at Wheeler Lock.

Detailed performance score for miter gate position indicator at Wheeler Lock and Dam (visited 22 June 1999)				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Proximity Controls Rotary Position Transmitter and Switch Model #35AD1				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	56

Table B-58. Performance Form for Sector Gate Position Indicator at Calcasieu Lock.

Detailed performance score for sector gate position indicator at Calcasieu Lock (visited 16 march 1999)				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: cam and bull gear				
How would you rate the technical support	1	1	2	1
How would you rate the access to spare parts	3	1	6	3
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	1	6	3
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	47

Table B-59. Performance Form for Lift Gate Position Indicator at Wilson (main) Lock.

Detailed performance score for lift gate position indicator at Wilson (main) lock visited 21 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	56

Table B-60. Performance Form for Miter Gate Position Indicator at Lock 1.

Detailed performance score for miter gate position indicator at Lock 1 visited 2 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Telemecanique XSE-C107130 limit switch				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	56

Table B-61. Performance Form for Sector Gate Position Indicator at Leland-Bowman Lock.

Detailed performance score for sector gate position indicator at Leland-Bowman Lock visited 15 March 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Westinghouse traveling nut limit switch				
How would you rate the technical support	1	0	2	0
How would you rate the access to spare parts	3	0	6	0
How would you rate the compatibility of new replacements for old parts	3	1	6	3
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	1	6	3
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	1	6	3
Compare this device's accuracy to others used for this application	2	1	4	2
SCORE			56	35

Table B-62. Performance Form for Miter Gate Position Indicator at Lockport Lock.

Detailed performance score for miter gate position indicator at Lockport Lock visited 16 June 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Allen Bradley Bul. 802T-ATP limit switch				
How would you rate the technical support	1	2	2	2
How would you rate the access ro spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	1	4	2
SCORE			56	52

Table B-63. Performance Form for Miter Gate Position Indicator at Winfield Lock and Dam.

Detailed performance score for miter gate position indicator at Winfield Lock and Dam visited 4 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Astrosystems, Inc Durapot HDC-24CRB				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	0	4	0
How would you rate the ease of troubleshooting of this device	3	1	6	3
Reliability Score				
How would you rate this device's reliability	3	1	6	3
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	1	6	3
Compare this device's accuracy to others used for this application	2	1	4	2
SCORE			**56**	**39**

Table B-64. Performance Form for Lift Gate Position Indicator at Lockport Lock.

Detailed performance score for lift gate position indicator at Lockport Lock visited 16 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Allen Bradley Encoder Absolute Optical PLC-Type 845C-MJZ3DL3LN4				
How would you rate the technical support	1	2	2	2
How would you rate the access ro spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			**56**	**54**

Table B-65. Performance Form for Miter Gate Position Indicator at Bonneville Lock.

Detailed performance score for gate position indicator at Bonneville and Dam visited 1 March 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer: Astrosystems Inc. Durapot PT HDC1000 rotating shaft position transmitter				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			**56**	**56**

Table B-66. Performance Form for Sector Gate Position Indicator at Port St. Lucie Lock.

Detailed performance score for sector gate position indicator at Port St. Lucie Lock visited February 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Henschel Corp. Synchro-transmitter model 5T				
How would you rate the technical support	1	2	2	2
How would you rate the access ro spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			**56**	**54**

Valve Position Indicator

At most locks, the position of the culvert valves during their travel from open to closed is indicated by a series of limit switches positioned along the path of motion of the valve machinery. These mechanical switches come either normally open or normally closed. As the lock machinery moves the valve, a physical contact on the switch is made. Once the switch is triggered, it sends a discrete opened/closed signal to the PLC system indicating such. This type of position indication is very reliable and accurate as long as the limit switches function properly. However, at very busy locks, the constant physical movement and contact of the switches causes them to fail. To overcome this, many locks began using magnetic switches or proximity switches to replace the mechanical switches. These switches have the added advantage of not making contact with the machinery. Another type of position indication device is the rotating shaft position transmitter. This device attaches directly to the machinery operating a valve. As the motor rotates, it sends an analog signal to the PLC system indicating exactly how much the machinery has rotated. The PLC is then programmed to calculate the distance the valve has traveled from this information. The last type of position indication device encountered in this study is the rotating encoder. It performs much the same as the rotating shaft position transmitter, except that it has fewer moving parts and is less likely to fail as a result of wear. The evaluation forms for the valve position indicators are found in Tables B-67 through B-84.

Table B-67. Performance Score for Valve Position Indicator at Lock No. 24.

Detailed performance score for valve position indicator at Lock No. 24 visited 26 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: traveling nut limit switch				
How would you rate the technical support	1	1	2	1
How would you rate the access to spare parts	3	1	6	3
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	1	4	2
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	1	4	2
SCORE			**56**	**46**

Table B-68. Performance Score for Valve Position Indicator at Melvin Price Locks and Dam.

Detailed performance score for valve position indicator at Melvin Price Locks and Dam visited 25 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Cutler Hammer E51AIT16PU Form C limit switch				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			**56**	**56**

Table B-69. Performance Score for Valve Position Indicator at Lock No. 27.

Detailed performance score for valve position indicator at Locks No. 27 visited 26 May 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: traveling nut limit switch				
How would you rate the technical support	1	1	2	1
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	1	6	3
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	1	4	2
How would you rate the ease of troubleshooting of this device	3	1	6	3
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	45

Table B-70. Performance Score for Valve Position Indicator at Barkley Lock.

Detailed performance score for valve position indicator at Barkley Dam and Lake Barkley visited 2 August 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Proximity Controls Rotary Position Transmitter and Switch Model #35AD1				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	56

Table B-71. Performance Score for Valve Position Indicator at Wilson Main Lock.

Detailed performance score for valve position indicator at Wilson (main) lock visited 21 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: BRX FA-Solver Type 800123-R				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			**56**	**56**

Table B-72. Performance Score for Valve Position Indicator at Wheeler Lock and Dam.

Detailed performance score for valve position indicator at Wheeler Lock and Dam visited 22 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Proximity Controls Rotary Position Transmitter and Switch Model #35AD1				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			**56**	**56**

Table B-73. Performance Score for Valve Position Indicator at Winfield Main Lock.

Detailed performance score for valve position indicator at Winfield Lock and Dam (visited 4 June 1999)				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Astrosystems, Inc DuraPot HDC-24RB rotating shaft position indicator				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	0	4	0
How would you rate the ease of troubleshooting of this device	3	1	6	3
Reliability Score				
How would you rate this device's reliability	3	1	6	3
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	1	6	3
Compare this device's accuracy to others used for this application	2	1	4	2
SCORE			56	39

Table B-74. Performance Score for Valve Position Indicator at Lock 1, St. Paul.

Detailed performance score for valve position indicator at Lock 1 (visited 2 June 1999)				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Telemecanique XSE-C107130 limit switch				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	56

Table B-75. Performance Score for Valve Position Indicator at Lock 25.

Detailed performance score for valve position indicator at Lock No. 25 (visited 26 May 1999)				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Traveling Nut Limit Switch				
How would you rate the technical support	1	1	2	1
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	55

Table B-76. Performance Score for Valve Position Indicator at Lock 24.

Detailed performance score for valve position indicator at Lock No. 24 visited 26 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: traveling nut limit switch				
How would you rate the technical support	1	1	2	1
How would you rate the access ro spare parts	3	1	6	3
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	1	4	2
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	1	4	2
SCORE			56	46

Table B-77. Performance Score for Valve Position Indicator at Lock No. 27.

Detailed performance score for valve position indicator at Locks No. 27 visited 26 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: traveling nut limit switch				
How would you rate the technical support	1	1	2	1
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	1	6	3
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	1	4	2
How would you rate the ease of troubleshooting of this device	3	1	6	3
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	45

Table B-78. Performance Score for Valve Position Indicator at Barkley Lock.

Detailed performance score for valve position indicator at Barkley Dam and Lake Barkley visited 2 August 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Proximity Controls Rotary Position Transmitter and Switch Model #35AD1				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	56

Table B-79. Performance Score for Valve Position Indicator at Wilson Main Lock.

Detailed performance score for valve position indicator at Wilson (main) lock visited 21 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: BRX FA-Solver Type 800123-R				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			**56**	**56**

Table B-80. Performance Score for Valve Position Indicator at Wheeler Lock and Dam.

Detailed performance score for valve position indicator at Wheeler Lock and Dam visited 22 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Proximity Controls Rotary Position Transmitter and Switch Model #35AD1				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			**56**	**56**

Table B-81. Performance Score for Valve Position Indicator at Winfield Main Lock.

Detailed performance score for valve position indicator at Winfield Lock and Dam (visited 4 June 1999)				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Astrosystems, Inc DuraPot HDC-24RB rotating shaft position indicator				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	0	4	0
How would you rate the ease of troubleshooting of this device	3	1	6	3
Reliability Score				
How would you rate this device's reliability	3	1	6	3
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	1	6	3
Compare this device's accuracy to others used for this application	2	1	4	2
SCORE			56	39

Table B-82. Performance Score for Valve Position Indicator at Lock 1, St. Paul.

Detailed performance score for valve position indicator at Lock 1 (visited 2 June 1999)				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Telemecanique XSE-C107130 limit switch				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	56

Table B-83. Performance Score for Valve Position Indicator at Lock 25.

Detailed performance score for valve position indicator at Lock No. 25 (visited 26 May 1999)				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Traveling Nut Limit Switch				
How would you rate the technical support	1	1	2	1
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	55

Table B-84. Performance Score for Valve Position Indicator at Lock 24.

Detailed performance score for valve position indicator at Lock No. 24 visited 26 May 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: traveling nut limit switch				
How would you rate the technical support	1	1	2	1
How would you rate the access ro spare parts	3	1	6	3
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	1	4	2
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	1	4	2
SCORE			56	46

Water Level Indicators

There were basically two types of water or "pool" level indicators encountered in the study: pressure transducers and tile gauges painted on the lock wall. A common comment at those locks that switched to pressure transducers to augment the tile gauges was that the electronic pool level indicators had improved lock operation. These automatic pool level indicators are especially helpful at those locks with electric motors because opening the miter gates against a differential in water level can damage electric motors. On the other hand, at those locks with hydraulic motors opening and closing the gates, the pool level indicators proved to be not quite as critical.

Though the same pressure transducers were being used at several different locks, the same performance was rarely encountered. Many locks have had to frequently recalibrate their pressure transducers. Others had difficulty obtaining adequate technical support from the manufacturer. The pool levels indicator evaluations forms are presented in Tables B-85 through B-99.

Table B-85. Performance Score for Pool Level Indicator at Lock 24.

Detailed performance score for pool level indicator at Lock No. 24 (visited 26 May 1999)				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Druck PTX 1880 pressure transducder				
How would you rate the technical support	1	2	2	2
How would you rate the access ro spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	56

Table B-86. Performance Score for Pool Level Indicator at Lock 25.

Detailed performance for pool level indicator at Lock No. 25 visited 26 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Druck PTX 1880 pressure transducer				
How would you rate the technical support	1	1	2	1
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	1	6	3
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	1	6	3
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			**56**	**49**

Table B-87. Performance Score for Pool Level Indicator at Melvin Price Locks and Dam.

Detailed performance score for pool level indicator at Melvin Price Locks and Dam visited 25 May 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Druck PTX 1830 pressure transducer				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			**56**	**56**

Table B-88. Performance Score for Pool Level Indicator at Lock 27.

Detailed performance score for pool level indicator at Locks No. 27 visited 26 May 1999				
Evaluation Criteria	weight	Raw Score	Max Score	Real Score
Manufacturer Score: Druck PTX 168				
How would you rate the technical support	1	1	2	1
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	1	6	3
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	52

Table B-89. Performance Score for Pool Level Indicator at Barkley Lock.

Detailed performance score for new trial pool level indicator at Barkley Dam and Lake Barkley visited 2 August 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Endress-Hauser Deltapilots Model #DB53A-AR71FD11GE20				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	56

Table B-90. Performance Score for Pool Level Indicator at Pickwick Lock and Dam.

Detailed performance score for pool level indicator at Pickwick Landing Lock and Dam visited 21 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Water marks on lock chamber				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	1	4	2
SCORE			**56**	**52**

Table B-91. Performance Score for Pool Level Indicator at Wheeler Lock and Dam.

Detailed performance score for pool level indicator at Wheeler Lock and Dam visited 22 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Tile Gage on the Wall				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	1	4	2
SCORE			**56**	**52**

Table B-92. Performance Score for Pool Level Indicator at Wilson Main Lock.

Detailed performance score for pool level indicator at Wilson (main) lock visited 21 June 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Celtek Electronics, Inc. LM7000 reflective wave level indicator				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	56

Table B-93. Performance Score for Pool Level Indicator at Calcasieu Lock.

Detailed performance score for pool level indicator at Calcasieu Lock visited 16 march 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Tile gauge on chamber wall				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	1	4	2
SCORE			56	52

Table B-94. Performance Score for Pool Level Indicator at Leland-Bowman Lock.

Detailed performance score for pool level indicator at Leland-Bowman Lock visited 15 March 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Tile Gage on Chamber Wall				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			**56**	**56**

Table B-95. Performance Score for Pool Level Indicator at Lock 1, St. Paul.

Detailed performance score for pool level indicator at Lock 1 visited 2 June 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Ametek Model 575				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			**56**	**56**

Table B-96. Performance Score for Pool Level Indicator at Lockport Lock.

Detailed performance score for pool level indicator at Lockport Lock visited 16 June 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Operator's Judgement				
How would you rate the technical support	1	2	2	2
How would you rate the access ro spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	1	6	3
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	1	6	3
Compare this device's accuracy to others used for this application	2	1	4	2
SCORE			56	46

Table B-97. Performance Score for Pool Level Indicator at Winfield Lock.

Detailed performance score for pool level indicator at Winfield Lock and Dam visited 4 June 1999				
Evaluation Criteria	Weight	Raw Score	Max Score	Real Score
Manufacturer Score: Druck PTX 161D pressure transducer				
How would you rate the technical support	1	1	2	1
How would you rate the access to spare parts	3	1	6	3
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	1	4	2
SCORE			56	48

Table B-98. Performance Score for Pool Level Indicator at Bonneville Lock.

Detailed performance score for pool level indicator at Bonneville and Dam visited 1 March 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer: Delta Controls Model 550 pressure transducer				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	2	4	4
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	2	4	4
SCORE			56	56

Table B-99. Performance Score for Pool Level Indicator at Port St. Lucie Lock.

Detailed performance score for water level indicator at Port St. Lucie Lock visited February 1999				
Evaluation Criteria	**Weight**	**Raw Score**	**Max Score**	**Real Score**
Manufacturer Score: Tile gauge on chamber wall				
How would you rate the technical support	1	2	2	2
How would you rate the access to spare parts	3	2	6	6
How would you rate the compatibility of new replacements for old parts	3	2	6	6
Body Material Score				
How would you rate the device's corrosion resistance	3	2	6	6
How would you rate the device's fitness for the work environment	3	2	6	6
Electrical Score				
How compatible is the signal this device transmits with its final receiver	2	2	4	4
How would you rate the ease of troubleshooting of this device	3	2	6	6
Reliability Score				
How would you rate this device's reliability	3	2	6	6
Compare this device's reliablity to others used for this application	2	1	4	2
Accuracy				
How would you rate this device's accuracy	3	2	6	6
Compare this device's accuracy to others used for this application	2	1	4	2
SCORE			56	52

Appendix C: Draft Corps of Engineer Guide Specifications (CEGS) for Lock Control Systems

CEGS SECTION 16900: CONTROL AND INSTRUMENTATION (Draft)

CEGS SECTION 16910: PROGRAMMABLE LOGIC CONTROLLER (Draft)

CEGS SECTION 16920: INDUSTRIAL PERSONAL COMPUTERS AND NETWORKS (Draft)

by

Andrew Schimpf and Michael Sommars

St. Louis District

1222 Spruce Street

St. Louis, MO 63103-2833

SECTION 16900
CONTROL AND INSTRUMENTATION

****

Note: This guide specification covers the requirements for procurement and installation of electrical and electronic field devices, including instrumentation cable, that provide input and output indication of the status of remote devices to the programmable logic controller and hardwired control systems at locks and dams. This guide specification is intended to cover both new lock construction as well as rehabilitation work. With some editing this guide specification can be used for other civil works projects. When using this guide specification the designer will be required to include portions of CEGS 16120 – INSULATED WIRE AND CABLE, CEGS 16403 – MOTOR CONTROL CENTERS, SWITCHBOARDS, AND PANELBOARDS, CEGS 16768 – FIBER OPTIC DATA TRANSMISSION SYSTEMS, CEGS 16792 – WIRE LINE DATA TRANSMISSION SYSTEM, CEGS 16794 – COAXIAL CABLE DATA TRANSMISSION MEDIA, and CEGS 16910 – PROGRAMMABLE LOGIC CONTROLLER. This guide specification is to be used in the preparation of project specifications in accordance with ER 1110-345-700 for military construction and in accordance with ER 1110-2-1201 for civil works construction.

****

PART 1 – GENERAL

1.1 REFERENCES.

****

Note: Issue date of references included in project specifications need not be more current than provided by the latest change (Notice) to this guide specification.

****

The publications listed below form a part of this specification to the extent indicated by the references thereto. The publications are referred to in the text by basic designation only.

American National Standards Institute (ANSI).

C 2	(1997) National Electrical Safety Code

American Society for Testing Materials (ASTM).

B 344	(1992) Drawn or Rolled Nickel-Chromium and Nickel-Chromium-Iron Alloys for Electrical Heating Elements

National Electrical Manufacturers Association (NEMA).

ICS 2	(1993) Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated No More than 2000 Volts AC or 750 Volts DC
ICS 6	(1993) Industrial Controls and Systems Enclosures

ICS 7	(1993) Industrial Control and Systems, Adjustable-Speed Drives
MG 1	(1993; Rev thru Jun 1997) Motors and Generators
WC 5	(1992; Rev thru 1996) Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

National Fire Protection Association (NFPA).

70-99	1999 National Electric Code

1.2 SYSTEM DESCRIPTION
****
Note: It is recommended that the designer prepare detailed engineered plans to accompany this specification. Plans should show all significant arrangements, sizes, capacities, quantities, wiring and all information necessary to convey to a contractor the intention of the design and to facilitate successful biding and construction of the control and instrumentation systems.
****
The work provided for herein consists of furnishing all plant, labor, material, and equipment for the installation and testing of the control and instrumentation systems as specified herein [**and as shown on the drawings.**] Unless specified otherwise all electrical material and equipment shall conform to the requirements of SECTION [**CEGS 16120 – INSULATED WIRE AND CABLE, CEGS 16403 – MOTOR CONTROL CENTERS, SWITCHBOARDS, AND PANELBOARDS, CEGS 16768 – FIBER OPTIC DATA TRANSMISSION SYSTEMS, CEGS 16792 – WIRE LINE DATA TRANSMISSION SYSTEM, and CEGS 16794 – COAXIAL CABLE DATA TRANSMISSION MEDIA**]. The scope of this project includes networking different vendor's equipment to a common communication network and computerized control system. It shall be the responsibility of the Contractor to provide approved systems integration services and to furnish and install all materials, hardware, software, and testing, as required, to provide fully functional/communicating networks for instrumentation and control systems as follows:

1) Miter gate control system, including position transducers, lever operated limit switches, proximity and magnetic switches, cable and wiring

2) Culvert valve control system, including position transducers, lever operated limit switches, proximity and magnetic switches, cable and wiring

3) Dam gate control system, including position transducers, cam operated limit switches, proximity and magnetic switches, cable and wiring

4) Water level sensing system, including pressure transducers, junction boxes, power supplies, cable and wiring

5) Adjustable Frequency Drive Systems

6) Miscellaneous control systems, [**such as compressed air bubbler systems, traffic lights, pleasure craft signals, lock and dam lighting systems, navigation lights, access gates, and signal horns.**]

7) Fabrication and installation of control consoles

8) Installation of all control, instrumentation, and fiber-optic cables

9) Testing of all control systems

10) Training of Government operating personnel

1.3 SUBMITTALS

****

Note: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.

Indicate submittal classification in the blank space using "GA" when the submittal requires Government approval or "FIO" when the submittal is for information only.

****

Government Approval is required for submittals with a "GA" designation; submittals having an "FIO" designation are for information only. The following shall be submitted in accordance with Section 1330 SUBMITTAL PROCEDURES:

[SD-16900-01 Cable.
Fiber-optic cable (GA)
Network communication cable (GA)
Twisted pair network cable (GA)
Coax (GA)
Twinaxial and triaxial signal cable (GA)
I/O Rack Wire and Wiring Diagrams (GA)

SD-16900-02 Control Stations and I/O Rack Enclosures
Control Cabinets, Construction, Painting, and Installation (GA)
Power Supplies (GA)
Line Conditioner (GA)
Terminal Blocks (GA)
Ventilation Fan (GA)
Air Conditioner Unit (GA)
Wire and Cable (GA)
Wiring Diagrams (GA)
Pushbuttons and Switches (GA)
Indicating Lights (GA)
Displays (GA)

SD-16900-03 Transducers
Rotating shaft position transducers, wiring (GA)
Pressure transducers, wiring (GA)
Power supplies (GA)
RTDs, wiring (GA)
Inclinometers, wiring (GA)

SD-16900-04 Limit Switches
Cam operated, wiring (GA)
Lever operated, wiring (GA)
Magnetic, wiring (GA)
Proximity, wiring (GA)
Photocell, wiring (GA)

SD-16900-05 Adjustable Frequency Drives.
Adjustable Frequency Drive Inverters (GA)
Network Communications (GA)
Installation and Wiring (GA)

SD-16900-06 Schedules.
Control and Instrumentation Systems Training (GA)

Control and Instrumentation Systems Testing (GA)]

1.4 PROJECT/SITE CONDITIONS

1.4.1 Environmental Requirements. The environment into which the electrical equipment will be installed is an outdoor facility subject to 100 percent humidity and temperature variations between [ ] degrees [**C**][**F**] and [ ] degrees [**C**][**F**]. The Contractor shall ensure that during installation all equipment is properly handled and stored so that it will not be adversely affected by the above conditions. The Contractor shall also ensure that the final installation of equipment meets the environmental requirements of the manufacturer.

1.4.2 Existing Conditions

****

Note: The designer should use this section to delineate any special existing conditions that affect the work as specified herein. This is an important section for contracts that include rehabilitation of lock control systems. In some cases existing machinery and/or electric power distributions systems will be reused by the contractor. These items should be explained in this part of the specification using sufficient detail to fully convey existing conditions and requirements necessary for a contractor to successfully bid and complete the contract work.

****

1.5 DELIVERY, STORAGE, AND HANDLING

Equipment specified in this section, comprised of electrical and electronic components, shall be scheduled for shipment to arrive on the job site no more than [ ] days

****

Note: The amount of time electronic equipment can be stored at the job site is specified to preclude prolonged storage and possible obsolescence of some equipment. Large construction contracts can have durations of several years and some electronic equipment can go through several revised releases during that time. The designer should be careful to allow enough lead-time not to effect the construction schedule but not excessive time. Sixty days is a good starting point. The designer should refine this for each project.

****

prior to its scheduled installation date. Upon delivery at the work site, the Contractor shall store all electrical and/or electronic equipment in areas [**as designated on the drawings**]. The conditions under which any equipment or materials are to be stored shall be in accordance with the equipment manufacturer's recommendations and with the best standard practices to ensure that all equipment and materials will be in pristine condition at the time of installation. The Contractor shall familiarize itself with regard to the location of all other equipment, materials, and conditions that may affect the electrical work sequence so as to minimize any interference with other installations or to subject any items to detrimental conditions. The exact storage location of all electrical and electronic items shall be [**as shown on the drawings**] subject to the approval of the Contracting Officer.

1.6 STANDARD PRODUCTS

Unless otherwise approved by the Contracting Officer, the materials and equipment to be furnished under this specification shall be standard products of manufacturers regularly engaged in the production of such equipment and shall be the manufacturer's latest commercially available "off the shelf" design. Items of equipment proposed for use under these specifications shall essentially duplicate equipment that has been in satisfactory use at least two years prior to bid opening. Like equipment for similar service shall be of the same manufacturer, and when of the same size and rating, shall be interchangeable. Equipment shall be supported by a service organization that is, in the opinion of the Contracting Officer, reasonably convenient to the site.

1.7 GENERAL ARRANGEMENTS

The general arrangements and approximate locations of the electrical equipment, conduit and wiring connections shall be [**as indicated on the drawings**]. The Contractor may, however, subject to the approval of the Contracting Officer, modify the layout [**indicated on the drawings or**] specified herein, to more readily conform to the space available and to the actual equipment proposed for use. Should the approved electrical equipment furnished be of a different size than indicated, the Contractor at his own expense shall make the necessary adjustments to the branch circuit wiring (8 AWG and smaller), disconnecting devices, branch-circuit protection, component wiring, component installation, I/O rack addressing, PLC programming, I/O rack fabrication and installation, and space requirements to accommodate the equipment actually installed.

1.8 QUALIFICATIONS

All work shall be performed in a skillful and workmanlike manner in accordance with the best modern shop practice for the manufacture of finished products of a nature similar to those covered by these specifications, and shall be performed by mechanics especially skilled for each kind of work and under competent supervision and direction. All materials and equipment shall be installed in accordance with recommendations of the manufacturer as approved by the Contracting Officer. Workmanship shall be of the highest grade and in accordance with modern practice.

1.9 SEQUENCING AND SCHEDULING

****

Note: This paragraph includes any special sequencing or scheduling of work unique to the project. Rehabilitation of existing lock control systems often will require special sequences and schedules and these should be spelled out in sufficient detail to convey the importance to the Contractor. Lock closure times and other limitations such as requirements for back-up generator sets or temporary control systems should be included here as technical requirements necessary for a Contractor to bid and construct the project.

****

1.10 WARRANTY [AND EXTENDED MAINTENANCE]

All equipment and material installed under this section shall be warranted to be free of defects in workmanship and material for a minimum of one year after acceptance by the Contracting Officer. The Contractor shall make written transfer of all manufacturers' warranties to the Government upon acceptance of the work by the Contracting Officer.

****
Note: This section should be used to include any requirements for extended maintenance contracts. It is often a good idea to use the same contractor or sub-contractor that installed the equipment as a long-term maintenance contractor. Terms and conditions of the contract should be clearly spelled out and it should be clear how the contractor is to bid the maintenance portion of the contract.
****

1.11 CODE COMPLIANCE

All work, specified herein [**or shown on the drawings**] shall conform to the applicable requirements of NFPA Code No. 70 National Electric Code, ANSI C2 National Electrical Safety Code, and SECTIONS [**CEGS 16120 – INSULATED WIRE AND CABLE, CEGS 16403 – MOTOR CONTROL CENTERS, SWITCHBOARDS, AND PANELBOARDS, CEGS 16768 – FIBER OPTIC DATA TRANSMISSION SYSTEMS, CEGS 16792 – WIRE LINE DATA TRANSMISSION SYSTEM, and CEGS 16794 – COAXIAL CABLE DATA TRANSMISSION MEDIA.**]

PART 2 - PRODUCTS

2.1 CONTROL AND INSTRUMENTATION CABLE.

****
Note: If the designer does not intend to use a section for general electrical requirements including wire and cable, appropriate portions of CEGS 16120 WIRE AND CABLE will have to be incorporated here.
****

2.1.1 General. Unless specified otherwise, all cables shall comply with the applicable requirements for wire and cable as specified in SECTION [**CEGS 16120 – INSULATED WIRE AND CABLE**]. In all cases instrumentation cables shall be as recommended by the manufacturer of the applicable equipment provided it is approved by the Contracting Officer.

2.1.2 Analog Signal Cable.

2.1.2.1 General. Cables for analog signals shall be of the shielded twisted-pair type, and shall be capable of withstanding extreme conditions of temperature, humidity, and frequent submersions for long periods of time.

2.1.2.2 Conductors. Conductors shall be tinned, stranded copper and shall not be smaller than No. 22 AWG for multiple pair cables and 18 AWG for single pair cables, unless approved by the Contracting Officer.

2.1.2.3 Voltage Ratings. All analog signal cables shall have a minimum rating for use at 300 V.

2.1.2.4 Insulation. Insulation shall be moisture resistant rubber or cross-linked-thermosetting-polyethylene. Individual conductors in cable shall have colored insulation (ICEA Method 1). Other color coding methods will not be accepted. Color-coding shall be as specified for shielded control cables in SECTION [**CEGS 16120 – INSULATED WIRE AND CABLE**].

2.1.2.5 Shielding. Shielding shall consist of aluminum-mylar foil type and shall have coverage of not less than 100 percent. In addition, each pair will have an individual copper drain wire not smaller than #22 AWG. Where connections are

made at plugs, the shielding shall be interconnected by a copper conductor and soldered with a resin core solder.

2.1.2.6 Jackets. Jackets on analog signal cables shall be of flame-retardant poly-vinyl chloride (PVC). Interstices shall be filled with suitable jute filler.

2.1.2.7 Testing. All analog signal cables shall be tested in accordance with the manufacturer's written recommendations.

2.1.3 Input/Output Rack Wiring.

2.1.3.1 General. I/O Rack wiring conductors shall be provided as indicated elsewhere in this specification [**and shown on the drawings**]. All I/O racks shall be factory wired to terminal boards using gray or red SIS No. 16 switchboard wire. Switchboard wire shall be stranded copper wire with 600-volt flame-retardant type SIS insulation and extra flexible (Class K) stranding.

****

Note: The designer may want to consider using the PLC manufacturers I/O card to terminal board wiring systems. The designer shall check to insure that current ratings are not exceeded for the cabling system and the I/O cards.

****

2.1.3.2 PLC Remote Rack Communication Cables. The cables used to provide communication between PLC components shall be the fiber-optic type as recommended or provided by the PLC manufacturer.

2.1.3.3 PLC/IPC Ethernet Communication Cable. The cables used to provide communications between the PLC and the IPCs shall be ThinWire Ethernet coax cable, Cat 5 twisted-pair Ethernet, or Fiber Optic, as recommended by the manufacturer of the PLC System (SECTION 16910 – Programmable Logic Controller), the Graphical User Interface software (SECTION 16920 – Industrial Personal Computers and Networks), or the PLC System Supplier (System Integrator), and approved by the Contracting Officer.

****

Note: The designer should consider the distance between the PLC communication cards and the IPC network hub. Fiber optic cable may be a necessary requirement and should be so specified in this paragraph.

****

2.1.4 Fiber Optic Cable

2.1.4.1 General. Fiber Optic cable provided [**as shown on the drawings and/or**] as required by these specifications shall meet the following requirements unless otherwise recommended by the manufacturer and approved by the Contracting Officer.

2.1.4.2 Construction. Fiber Optic cable shall be FDDI-grade heavy-duty type using the water blocking gel-filled loose buffer tube construction with inner core 62.5 microns and outer clad 125 microns. Single and duplex fiber cable shall have fibers contained in plastic tubes that are encased in braided Kevlar material strands. Multi-fiber cable shall have a fiberglass epoxy rod strength member.

2.1.4.3 Jackets. The stranded core shall be covered with an inner jacket made of heavy duty Poly-vinyl Chloride, a Kevlar Braid, and an outer jacket made of black Polyethylene.

****

Note: The designer may want to consider using light-duty, non-jacketed fiber optic cable in lieu of the heavy duty type, depending on the environment and application. This would eliminate the need for breakout cable and boxes.

****

2.1.4.4 Breakout Cable and Boxes. Termination points shall be provided with appropriately sized breakout boxes and breakout cables as recommended by the manufacturer of the fiber optic cable for the intended use.

2.1.5 Water Level Sensing Cable.

2.1.5.1 General. Cable for the water level sensing system shall be of the twisted pair shielded type.

2.1.5.2 Conductors. Conductors shall be tinned, stranded copper and shall not be smaller than No. 18 AWG.

2.1.5.3 Voltage Ratings. All cables shall have a minimum rating for use at 300V.

2.1.5.4 Insulation. Insulation shall be polyethylene not less than 7/64-inch thick. Individual conductors in cable shall have colored insulation (ICEA Method 1). Other color coding methods will not be accepted. Color-coding shall be as specified for shielded control cables in Section [**CEGS 16120 – INSULATED WIRE AND CABLE**].

2.1.5.5 Shielding. Shielding shall consist of a copper drain wire AND an aluminum-mylar foil type having coverage of not less than 100 percent.

2.1.5.6 Jackets. Jackets on cables shall be of flame-retardant polyvinyl chloride (PVC).

2.1.5.7 Testing. All cables shall be tested in accordance with the manufacturer's written recommendations.

2.1.6 Packaging. All control, instrumentation, communication, and fiber-optic cables shall be shipped on industry standard non-returnable reels. The radius of each reel shall be at least two inches greater than the distance from the axis of the reel to the outside of the outermost layer of cable on the reel. Cable ends, whether exposed or concealed, shall be sealed with heat shrinkable caps. Cap sizes shall be as recommended by the manufacturer for the cable OD and materials. Caps shall contain sufficient adhesive so that shrinkage of the cap during application results in formation of a positive watertight seal capable of withstanding complete immersion or totally exposed storage over a period of several months without permitting the entrance of moisture.

2.2 CONTROL CONSOLE CONSTRUCTION.

2.2.1 General. The Contractor shall furnish and install control consoles to be located [**as shown on the drawings**]. These consoles shall consist of a lower section to house the Industrial Personal Computer (IPC) components, middle desk section for IPC keyboard and a console top for the viewing monitors. The Contractor shall, at its option, provide "off-the-shelf" standard console components or, retain the services of a competent panel manufacturer, herein referred to as "Console Manufacturer", to design and construct the control consoles. As soon as possible after Notice to Proceed, the Contractor shall submit for approval the name of the console manufacturer along with its qualifications. Wire and cable shall comply with the requirements of SECTION [**CEGS 16120 – INSULATED WIRE AND CABLE**].

****

Note: It is better whenever possible to use standard modular off the shelf control console components. These can easily be relocated, altered, or supplemented when necessary. However, it is recognized that certain situations will require custom made control consoles. The designer will be responsible for determining this.

****

2.2.2 Construction. The Console Manufacturer shall be responsible for designing, constructing, and supervising the installation of the control consoles. The Console Manufacturer shall develop construction drawings showing sufficient detail to ensure that the consoles meet the intent of the specifications [**and drawings**] and will physically fit in the desired locations [**as shown on the drawings**]. [**Dimensions on the drawings are for general guidance only**]; the contractor shall be responsible for final determination of all dimensions subject to the approval of the Contracting Officer.

2.2.2.1 General. Each console section shall be completely enclosed at front, rear, top, bottom, and both sides with cable entry from the bottom. The console structure shall be constructed of leveled 12 USS gauge steel sheets and formed steel subframe members rigidly welded together to form a self-supporting structure. Welds on exposed surfaces of the structure shall be ground smooth. Finished surfaces shall be free of waves, bellies and other imperfections.

2.2.2.2 Doors. Doors shall be provided for each enclosure [**as shown on the drawings**]. Doors shall have flush mount stainless steel latches and locks, full length stainless steel 'piano' type hinges, and sponge rubber gaskets. Doors shall be arranged to swing out through not less than 105 degrees from the closed position. Stops shall be provided as required to limit door swing and prevent damage to hinges or adjacent equipment. The clearance between any edge of a hinged door, when closed, and any adjacent panel shall be uniform and shall not exceed 1/8-inch.

2.2.3 Wiring.

2.2.3.1 General. All insulated wires and cables used within the control consoles shall conform to the requirements of SECTION [**CEGS 16120 – INSULATED WIRE AND CABLE**].

2.2.3.2 Installation. All wiring shall be neatly and carefully installed in wiring ducts, raceways, or bundled and secured with wire wraps or lacing. Wiring shall be terminated at terminal blocks plainly lettered or marked [**in accordance with the drawings**].

2.2.3.3 [**Quick Disconnects. All wires and cables entering the control consoles shall be provided with easily accessible locking plug-type disconnecting means. In case of flood conditions, the control consoles are intended to be disconnected and removed.**]

2.2.3.4 Clearance. Sufficient clearance shall be provided for all leads and lead identification. All leads for external circuit wiring shall be connected to grouped terminal blocks located for convenient connection of external circuits. Splices shall not be permitted in any console wiring.

2.2.4 Finish.

2.2.4.1 General. All interior and exterior surfaces of the control consoles shall be finished with a weather resistant, rust inhibiting paint.

2.2.4.2 Surface Preparation. All steel surfaces shall be chemically cleaned to provide a bond between paint and metal surfaces to help prevent the entrance of moisture and formation of rust under the paint film. After preparation of surfaces, all pits or indentations shall be filled with a 100 percent solid catalyzed

epoxy putty compound. After hardening of the putty filler, the filled areas shall be sanded smooth. Exterior surface shall be smooth and uniform to receive the paint.

2.2.4.3 Primer. After cleaning and filling, one coat of ferrous metal primer shall be applied to all ferrous surfaces to receive paint and shall have a minimum of 1 to 2 mils dry film thickness.

2.2.4.4 Paint.

2.2.4.4.1 General. All paints shall be spray applied to produce a smooth, uniform coat, free of defects. Each coat shall be properly cured according to the manufacturer's instructions before application of succeeding coats.

2.2.4.4.2 Interior Surfaces. Interior surfaces shall be painted with no less than two coats of synthetic semi-gloss white enamel. Finish shall have a minimum of 4 to 5 mils dry film thickness. The Contractor shall restore any damaged places in the paint after the installation of equipment in the control consoles.

2.2.4.4.3 Exterior Surfaces. Exterior surfaces shall be painted with not less than two coats of synthetic flat finish enamel to produce a non-glare surface of not less than 4 to 5 mils dry film thickness. The color shall be [**determined by the Contracting Officer after the award of the Contract**]. The Contractor shall restore any damaged places in the paint after the assembly of the control consoles.

2.2.5 Console-Mounted Devices and Components.

2.2.5.1 General. Unless stated otherwise, all console-mounted devices and components shall be in accordance with SECTION [**CEGS 16403 – MOTOR CONTROL CENTERS, SWITCHBOARDS, AND PANELBOARDS**].

2.2.5.2 Emergency Stop Button. The consoles shall each have an illuminated red target "mushroom-head" emergency stop button. The pushbutton shall be double-pole and of the push-to-stop, pull-to-reset type, [**and provided with a hinged lexan cover to prevent accidental shutdowns**]. Separate normally closed contacts on the button shall be used as an input to the PLC system and hardwired to an emergency stop relay system [**as shown on the drawings**].

****

Note: The designer may want to consider having hardwired controls for other features such as a warning horn, or an audible alarm.

****

****

Note: The following paragraph will need to be modified if Industrial Personal Computers are not specified to be provided in the same contract.

****

2.2.5.3 Computer Control System Components. All panel-mounted equipment associated with the Computer Control System shall be as specified in SECTION 16920 - INDUSTRIAL PERSONAL COMPUTERS AND SOFTWARE.

2.2.5.4 Enclosure Heater. Each enclosure shall be provided with an electrical heater of the [**Edison screw base type**][**strip type**][**silicone rubber insulated type**]. The heaters shall be mounted [**as shown on the drawings**]. Heaters shall be 120V, and sized to prevent condensation within the console. The heaters shall work in conjunction with a thermostat to provide operation below an adjustable set temperature.

2.2.6 Nameplates. Each major component of equipment shall have the manufacturer's name, address, and catalog number on a nameplate securely attached to the equipment in a conspicuous location. In addition, specific nameplates shall

be provided as **[delineated on the drawings]**. Nameplates shall be fabricated of laminated plastic of sufficient size to accommodate minimum size lettering of ¼". Engraving shall be white letters on black background.

2.2.7 Shelves. Pullout shelves shall be provided for supporting the CPU chassis. The shelves shall allow the chassis to be pulled out of the control consoles to a sufficient extent to easily allow cable connections and other routine maintenance tasks. The shelves shall be free rolling, with ball bearing guides, and strong enough to support the chassis and at least an additional 50 pounds at the front edge with the shelf pulled to its greatest extension from the control consoles. Cable connections shall have sufficient slack to allow shelves to operate freely over the extended range.

2.2.8 Surge Suppression Receptacles. The control consoles shall be provided with surge suppression receptacles **[as shown on the drawings]**. The surge suppression receptacles shall be UL Listed, 20 amp, 115 VAC duplex type.

2.2.9 General Purpose Power Strips. The control consoles shall be provided with power strips **[as shown on the drawings]**. The power strips shall be UL Listed and include 6-outlets.

2.2.10 Exhaust Fan. Each enclosure shall be provided with an exhaust fan. The fan shall operate on 120 VAC, 60 Hz, single-phase power and deliver **[The designer shall specify for given size enclosure]** cubic feet per minute (CFM) of air at zero static pressure. The exhaust fan shall have an air outlet exhaust grille and filter at the air intake side of the fan. The fan shall work in conjunction with an adjustable thermostat to provide operation above a set temperature.

2.2.11 Shipping. The control consoles may be shipped in pieces. The consoles shall be individually packed in separate boxes, crates, or cartons as applicable. Consoles shall be as completely assembled as practical to minimize reassembly at the site. All sections and components, which are disassembled for shipment, shall be carefully packed, and marked to facilitate reassembly. All finished surfaces and metalwork shall be suitably wrapped or otherwise protected from damage during shipment. Shipping splits shall clearly be shown on the Console Manufacturer's submittal.

2.2.12 Factory Inspections. The Contractor shall notify the Contracting Officer 10 days prior to completion of the control consoles. At his option, the Contracting Officer may inspect the control consoles prior to shipment. If the control consoles do not pass this inspection, the Contractor shall make any necessary changes and adjustments to the equipment at no additional cost to the Government, and notify the Contracting Officer when ready for re-inspection.

2.2.13 Spare Parts. All spare parts shall be packaged, duplicates of the original parts furnished, and interchangeable therewith.

1) **[Quantity][3]** emergency stop buttons

2) **[Quantity][1]** power strips

3) **[Quantity][1]** exhaust fan

4) **[Quantity][10]** filters for the exhaust fan intake grille

2.3 PLC REMOTE RACK ENCLOSURES.

****

Note: For input/output racks intended to be installed in Motor Control Centers the designer should include special mounting and wiring requirements with the specifications for the MCC, CEGS 16403 – MOTOR CONTROL CENTERS, SWTICHBOARDS, AND PANELBOARDS.

****

2.3.1 General. All PLC remote rack enclosures shall be NEMA 4X stainless steel (exterior installation) and NEMA 12 stainless steel (interior). Sizes of enclosures shall be determined by the Contractor to accommodate the equipment as specified herein [**and shown on the drawings**]. [**Dimensions on the drawings are for general guidance only**]; the contractor shall be responsible for final determination of all dimensions subject to the approval of the Contracting Officer. [**The I/O rack installation in the Motor Control Centers shall be provided and coordinated by the manufacturer of the MCC**]. All enclosures shall comply with NEMA ICS 6. The enclosures shall be constructed in accordance with the manufacturer's standards, subject to approval by the Contracting Officer. All enclosures shall be self-supporting with subframe or plate framework as necessary to obtain proper stiffness and support. The body of the enclosures shall be a minimum of leveled USS 12 gauge stainless steel sheets and formed stainless steel members rigidly welded together to form a self supporting structure. Welds on exposed surfaces of the structure shall be ground smooth. Finished surfaces shall be free of waves, bellies and other imperfections.

2.3.2 Fabrication. All fabrication shall be of stainless steel plate with welded construction throughout. Welds shall be ground smooth, all corners shall be rounded, and all weld spatters cleaned. Corner construction shall be minimum of 1/8-inch inside radius. Enclosure construction shall meet NEMA 4X standards. The enclosures shall have completely sealed bottoms.

2.3.3 Surfaces. The surface of the enclosures shall be free from defects and marred areas. Finished surfaces shall be flat within 1/16-inch in 6 feet and shall be smooth with rounded edges. Finished surfaces shall be 3/16-inch thick. Any necessary cutouts and drillings shall be straight, accurate, and free of rough edges.

2.3.4 Doors. Doors shall be provided for each enclosure [**as shown on the drawings**]. Doors shall have triple point latch, stainless steel handle and lock, full length stainless steel 'piano' type hinges, and sponge rubber gaskets. Doors shall be arranged to swing out through 180 degrees from the closed position. Stops shall be provided as required to limit door swing and prevent damage to hinges or adjacent equipment. The clearance between any edge of a hinged door, when closed and any adjacent panel shall be uniform and shall not exceed 1/8-inch.

2.3.5 Framing. Each enclosure shall be provided with necessary framing, cross bracing, and stiffness to form a rigid, self-supporting type of structure. Vertical edges of sections shall be formed and bolted together so that no part of edges exposed to view will pass a 1/32-inch gauge. To prevent warping, stiffeners shall be provided to adequately support all heavy equipment. The panels, trim, door, and frames shall match and present a neat appearance when assembled as an enclosure.

2.3.6 **[Wall Mounting Reinforcements. The PLC I/O remote rack enclosures which are intended to be wall mounted shall have external stainless steel mounting feet. Mounting feet shall be sufficient in number and capacity to support the enclosure and all equipment contained within.]**

2.3.7 Subpanels. Each enclosure shall be provided with inner back and side subpanels, as required, for mounting all internal components. Subpanels shall be constructed of leveled USS 10-gauge carbon steel.

2.3.8 Finish.

2.3.8.1 General. Stainless steel surfaces shall not be painted. All interior carbon steel subpanel surfaces shall be finished with a weather-resistant, rust inhibiting paint.

2.3.8.2 Surface Preparation. All steel surfaces shall be chemically cleaned to provide a bond between paint and metal surfaces to help prevent the entrance of moisture and formation of rust under the paint film. After preparation of surfaces, all pits or indentations shall be filled with a 100 percent solid catalyzed epoxy putty compound. After hardening of the putty filler, the filled areas shall be sanded smooth. Surface shall be smooth and uniform to receive the paint.

2.3.8.3 Primer. After cleaning and filling, one coat of ferrous metal primer shall be applied to all ferrous surfaces to receive paint and shall have a minimum of 1 to 2 mils dry film thickness.

2.3.8.4 Paint. All paints shall be spray applied to produce a smooth, uniform coat, free of defects. Each coat shall be properly cured according to the manufacturer's instructions before application of succeeding coats.

2.3.8.5 Interior Surfaces. Interior subpanel surfaces shall be painted with no less than two coats of synthetic semi-gloss white enamel. Finish shall have a minimum of 4 to 5 mils dry film thickness. The Contractor shall restore any damaged places in the paint after the installation of equipment.

2.3.8.6 Exterior Surfaces. Exterior stainless steel surfaces shall not be painted.

2.3.9 Wiring Entry. Wiring into the enclosure shall enter through the [**bottom**][**top**][**sides**] of the enclosure by way of conduits using watertight conduit hubs complying to UL 514.

2.3.10 Enclosure Heater. Each enclosure shall be provided with an electrical heater of the [**Edison screw base type**][**strip type**][**silicone rubber insulated type**]. The heaters shall be mounted [**as shown on the drawings**]. Heaters shall be 120V, and sized to prevent condensation within the console. The heaters shall work in conjunction with a thermostat to provide operation below an adjustable set temperature.

2.3.11 Support Equipment.

2.3.11.1 Line Conditioner. Each PLC remote I/O rack enclosure shall have a line conditioner to be used exclusively for filtering power to the PLC I/O rack power supply. The line conditioner shall be terminal style, single phase, with a power rating of 150 percent of the calculated I/O rack load at each enclosure, 120 VAC input and output voltage, 60Hz, minimum 60dB Normal Mode Noise Attenuation at 100kHz, minimum 146 dB Common Mode Noise Attenuation at 100kHz, and shall be UL listed. The line conditioner shall be as recommended by the PLC manufacturer for the I/O racks and power supplies furnished under this contract.

2.3.11.2 Power Supply. Each PLC remote I/O rack enclosure shall have separate power supplies, as required, to power the pushbuttons, limit switches, pilot power for the PLC remote I/O cards, fiber-optic converters, and position transmitters. These power supplies shall not be used to power the water level sensing system transmitters. The water level sensing system power supplies shall be as specified in Paragraph 16900-[**2.7.3**]. Power supplies shall operate on 120 VAC, 60 Hz and shall be of the enclosed type and UL listed. Power supplies shall be sized at 150% of the anticipated load.

2.3.11.3 PLC I/O Racks. The I/O racks as provided by the PLC System Supplier shall be installed in the I/O rack enclosures using rubber, plastic, or other non-conductive material standoffs to isolate the racks from the metal sub panels.

The manufacturer of the PLC system shall make written approval of the installation.

2.3.11.4 **[Air Conditioners. For cooling the remote I/O racks, the Contractor shall provide air conditioning units. The units shall operate on [115/230][120/208] volts ac single phase 60 Hz, have capacity to maintain maximum [90 degrees F][32 degrees C] in the enclosure, and shall be provided as part of the I/O rack enclosure construction. The units shall meet the applicable standards of the [1999] ASHRAE Handbook - HVAC Applications. It shall be the responsibility of the Contractor to properly coordinate the specifying and installation of the I/O rack air conditioning units.]**

2.3.12 Wiring.

2.3.12.1 General. All wiring used within the I/O rack enclosures shall conform to the requirements of SECTION [**CEGS 16120 – INSULATED WIRE AND CABLE**]. The PLC equipment enclosures shall be completely wired at the factory, with the exception of field wiring and wiring between enclosures. Splices shall not be accepted in internal enclosure wiring.

2.3.11.2 Installation. All internal wiring shall be neatly and carefully installed in bundles. Wiring of different signal levels shall be separated by use of separate wire ducts, where practicable. A wire duct system shall be used [**where indicated on the drawings**]. Each wire shall be plainly marked to facilitate future maintenance. Wire marking methods shall be as specified in SECTION [**CEGS 16120 – INSULATED WIRE AND CABLE**].

2.3.11.3 Terminations. All internal wiring shall be terminated by means of approved pressure grip (solderless) lugs of the indented barrel type. The barrel of the lugs shall be indented into the conductor using a tool especially designed for the purpose. Post tongue indented terminals shall be used on all control wire terminations.

2.3.12.4 Terminal Blocks. All internal wiring shall be terminated at terminal blocks plainly lettered or marked in accordance with the drawings. Terminal blocks that are attached to are provided with approved PLC modules shall be considered in compliance with this specification. Terminal blocks shall be molded or fabricated type with barriers rated not less than 300 volts. Terminal blocks shall be knife-switch type with appropriate end sections, partitions, mounting rails, identifying label holder, and end brackets.

2.3.12.5 Spare Wires. All spare wires which are not terminated shall be neatly coiled and strapped to the bundle of used wire from which it originates. Spare wires shall be left as long as possible and shall have no insulation removed.

2.3.12.6 Clearance. Sufficient clearance shall be provided for all leads and lead identification. All leads for external circuit wiring shall be connected to grouped terminal blocks located for convenient connection of external circuits.

2.3.12.7 Conductors. Unless specified otherwise in these specifications or on the drawings, all wiring in the PLC remote I/O rack enclosures shall be factory installed using gray SIS No. 16 switchboard wire as specified in Paragraph 16900-[**2.1.3.1**]. All wiring between PLC components shall be as recommended by the manufacturer of the PLC equipment.

2.3.12.8 Inspection. The Contractor shall notify the Contracting Officer 10 days prior to completion of the PLC remote I/O rack enclosures. At his option, the Contracting Officer may inspect the enclosures. If an enclosure fails any inspection, the Contractor shall make the necessary changes and adjustments at no additional cost to the Government, and notify the Contracting Officer when ready for re-inspection. Shipment of the enclosures shall not be made until the completion of these inspections.

2.4 CULVERT VALVE CONTROLS.

2.4.1 General. The Contractor shall furnish and install all necessary connectors, cables, electronic equipment, electrical devices, and miscellaneous hardware to fulfill the control function specified herein and [**shown on the drawings**] for the lock filling and emptying culvert valves. The Contractor shall adjust the length of any manufacturer-supplied cable so that connection points are accessible without splices. Unless specified otherwise, all equipment and installation shall conform to SECTION [**CEGS 16120 – INSULATED WIRE AND CABLE, CEGS 16403 – MOTOR CONTROL CENTERS, SWITCHBOARDS, AND PANELBOARDS, CEGS 16768 – FIBER OPTIC DATA TRANSMISSION SYSTEMS, and CEGS 16792 – WIRE LINE DATA TRANSMISSION SYSTEM**]. The culvert valves shall normally be controlled from the IPC computer screens via PLC I/O [**and/or by manual control from pushbuttons on the MCC starter section**][**and/or by manual control from the minimal emergency hardwired back-up system**]. The Contractor shall furnish and install all enclosures, control relays, pushbuttons and other hardware [**as indicated on the drawings**] to construct the culvert valve control system.

****

Note: Following are specifications for different types of limit switches and transducers. The designer will have to include only those required for each project. Some projects may require the use of special limit switches or special mounting hardware. Mention is made of exiting limit switches because rehab projects may require that existing machinery be re-used.

****

2.4.2 Limit Switches. The Contractor shall furnish and install all cable, conductors, conduit and other necessary hardware to wire the [**new**][**existing**] culvert valve limit switches into the culvert valve control system. The limit switches shall be wired [**as shown on the drawings**]. [**Existing limit switches shall be thoroughly cleaned inside and outside of the limit switch enclosures, contacts cleaned, and actuating mechanism greased. Switches shall be re-tensioned to make proper electrical contact, and the contact areas silver-soldered and sanded smooth to form a good electrical contact surface.**]

2.4.2.1 Lever Operated Limit Switches. Limit switches shall be installed on the culvert valve machinery to prevent overstressing of mechanical components at both ends of the travel. Overtravel limit switches shall be hard-wired to the drive motor starter to de-energize the machinery [**motors**][**solenoids**] in overtravel conditions. Normal end-of-travel limit switches shall be wired to the PLC I/O system. Limit switch construction shall be NEMA 6P submersible, [**120VAC**][**24VDC**][**24VAC**], one normally open and one normally closed contact with 10 amp continuous rating, operating temperature range of [**-20 to 140 deg. F**][**-28 to 60 deg. C**], UL listed and [**side**][**front**] rotary standard spring return operating head. The operating shaft, rod and roller pin shall be made of corrosion resistant Type 303 stainless steel. The switch shall be factory pre-wired using STO type cable and the cable entrance and wire strands shall be epoxy sealed to protect against the entrance of water into the switch. The Contractor shall determine the cable length required. [**The designer is responsible for determining the type of switch control arm/linkage to provide with the switch to ensure proper operation of travel limits. This will vary by application.**] The Contractor shall be responsible for properly adjusting the limit switches to protect the machinery from damage due to overtravel.

2.4.2.2 Magnetic Limit Switches. Magnetic type end-of-travel [**/speed change**] limit switches shall be installed on the culvert valve machinery [**as shown on the drawings**]. The limit switches shall be UL listed, NEMA 6P, [**120VAC**][**24VDC**][**24VAC**], 10 amp continuous contact rating, one normally open and one normally closed contact, with stainless steel switch housing. The cable entrance and wire strands shall be epoxy sealed to protect against the entrance of water into the switch. The switch shall be factory pre-wired using STO type cable. The Contractor shall determine the cable length required. The Con-

tractor shall be responsible for adjusting the limit switches for proper operation at the normal machinery end-of-travel position.

2.4.2.3 Proximity Limit Switches. UL listed proximity type end-of-travel [/**speed change**] limit switches shall be installed on the culvert valve machinery [**as shown on the drawings**]. The proximity switches shall be unshielded [**120VAC**][**24VDC**][**24VAC**], [**25ma, for PLC operation only**] switch rating, one normally open and one normally closed output, NEMA 6P designed for submersion, with stainless steel barrel and housing. Operating range shall be [**Designer shall specify for each application**] inches with [**10**]% hysteresis, [**10**]% repeatability, and operating temperature range of [**-10 to 150 deg F**][**-25 to 70 deg C**]. The cable entrance and wire strands shall be epoxy sealed to protect against the entrance of water into the switch. The switch shall be factory pre-wired using SOOW-A rated cable. The Contractor shall determine the cable length required. The Contractor shall be responsible for adjusting the limit switches for proper operation at the normal machinery end-of-travel position.

2.4.3 Position Transducer. The Contractor shall furnish and install all cable, conductors, conduit and other necessary hardware to wire the [**new**][**existing**] culvert valve position transducers into the new culvert valve control system. The transducers shall be wired [**as shown on the drawings**].

2.4.3.1 Rotating Shaft Encoders. The culvert valve position transducers shall be UL listed rotating shaft type for converting the position of the valves and shall be a [ ]-turn, electromagnetic, absolute resolver type, capable of immediately returning the correct angular position after a power loss with no manual resetting required. The output of the transmitter shall be directly linearly proportional to the angular position of the rotating machinery shaft. The transmitter shall meet or exceed the following requirements:

(1)	Power Supply Voltage	24 VDC
(2)	Output Signal	4-20 mA (3-wire including power supply)
(3)	Accuracy	0.05 Percent
(4)	Shaft Diameter	[**0.625 inch**]
(5)	Operating Temperature	- 20 to 70 deg C

The transmitters shall include the following inherent features as standard equipment:

a. Built-in gas tube lightning and surge protection.

b. Corrosion resistant NEMA 4 housing.

c. Unlimited resolution.

The transmitters shall provide these features and meet these requirements without the need for any encoders, signal conditioners, or other electronics. The signal directly from the transmitter shall be used by the PLC analog input cards (SECTION CEGS 16910) to determine the valve position. All scaling and offsetting shall be accomplished in the PLC programming software. The transmitter 24 VDC power supplies shall be as specified in SECTION 16900-[**2.3.11.2**]. The Contractor shall program the PLC to condition the signal from the culvert valve rotating shaft position transducer to produce the correct position of the culvert valve through the full range of travel.

2.4.3.2 Hydraulic Cylinder Position Transducers. The position of the culvert valve shall be measured using a position tracking system built into the hydraulic cylinder and rod assembly. The transducer shall be furnished as part of the hydraulic system and shall be of the same manufacturer as the hydraulic cylinder. The output of the transducer shall be directly linearly proportional to the exten-

sion and retraction of the hydraulic rod. The transducer system shall meet or exceed the following requirements:

(1) Power Supply Voltage	**[24 VDC]**
(2) Output Signal	**[Quadrature encoder][Bi-directional Pulse Count][4-20ma]**
(3) Accuracy	**[0.1% FS]**
(4) Environmental	NEMA 3R

The hydraulic cylinder position tracking system shall provide these features and meet these requirements without the need for any encoders, signal conditioners, or other electronics. The signal, direct from the transmitter, shall be used by the PLC high speed counter or analog input cards (SECTION CEGS 16910) to determine the rod position. All scaling and offsetting shall be accomplished in the PLC programming software. The transducer power supplies shall be as specified in SECTION 16900-[**2.3.11.2**]. The Contractor shall program the PLC to condition the signal from the culvert valve hydraulic cylinder position tracking transducer to produce the correct position of the culvert valve through the full range of travel.

2.5 MITER GATE CONTROLS.

2.5.1 General. The Contractor shall furnish and install all necessary connectors, cables, electronic equipment, electrical devices, and miscellaneous hardware to fulfill the control function specified herein and [**as shown on the drawings**] for the lock miter gates. The Contractor shall adjust the length of any manufacturer-supplied cable so that connection points are accessible without splices. Unless specified otherwise, all equipment and installation shall conform to SECTION [**CEGS 16120 – INSULATED WIRE AND CABLE, CEGS 16403 – MOTOR CONTROL CENTERS, SWITCHBOARDS, AND PANELBOARDS, CEGS 16768 – FIBER OPTIC DATA TRANSMISSION SYSTEMS, and CEGS 16792 – WIRE LINE DATA TRANSMISSION SYSTEM**]. The miter gates shall normally be controlled from the IPC computer screens via PLC I/O [**and/or by manual control from pushbuttons on the MCC starter section**][**and/or by manual control from the emergency hardwired back-up system**]. The Contractor shall furnish and install all enclosures, control relays, pushbuttons and other hardware [**as indicated on the drawings**] to construct the miter gate control system.

****

Note: Following are specifications for different types of limit switches and transducers. The designer will have to include only those required for each project. Some projects may require the use of special limit switches or special mounting hardware. Mention is made of exiting limit switches because rehab projects may require that existing machinery be re-used.

****

2.5.2 Limit Switches. The Contractor shall furnish and install all cable, conductors, conduit and other necessary hardware to wire the [**new**][**existing**] miter gate limit switches into the miter gate control system. The limit switches shall be wired [**as shown on the drawings**]. [**Existing limit switches shall be thoroughly cleaned inside and outside of the limit switch enclosures, contacts cleaned, and actuating mechanism greased. Switches shall be re-tensioned to make proper electrical contact, and the contact areas silver-soldered and sanded smooth to form a good electrical contact surface.**]

2.5.2.1 Lever Operated Limit Switches. Limit switches shall be installed on the miter gate machinery to prevent overstressing of mechanical components at both ends of the travel. Overtravel limit switches shall be hard-wired to the drive motor starter to de-energize the machinery motors in overtravel conditions. Normal

end-of-travel limit switches shall be wired to the PLC system. Limit switch construction shall be NEMA 6P submersible, **[120VAC] [24VDC] [24VAC]**, one normally open and one normally closed contact with 10 amp continuous rating, operating temperature range of **[-20 to 140 deg. F][-28 to 60 deg. C]**, UL listed and **[side][front]** rotary standard spring return operating head. The operating shaft, rod and roller pin shall be made of corrosion resistant Type 303 stainless steel. The switch shall be factory pre-wired using STO type cable and the cable entrance and wire strands shall be epoxy sealed to protect against the entrance of water into the switch. The Contractor shall determine the cable length required. **[The designer is responsible for determining the type of switch control arm/linkage to provide with the switch to ensure proper operation of travel limits. This will vary by application.]** The Contractor shall be responsible for properly adjusting the limit switches to protect the machinery from damage due to overtravel.

2.5.2.2 Magnetic Limit Switches. Magnetic type end-of-travel **[/speed change]** limit switches shall be installed on the miter gate machinery **[as shown on the drawings]**. The limit switches shall be UL listed, NEMA 6P, **[120VAC][24VDC][24VAC]**, 10 amp continuous contact rating, one normally open and one normally closed contact, with stainless steel switch housing. The cable entrance and wire strands shall be epoxy sealed to protect against the entrance of water into the switch. The switch shall be factory pre-wired using STO type cable. The Contractor shall determine the cable length required. The Contractor shall be responsible for adjusting the limit switches for proper operation at the normal machinery end-of-travel position.

2.5.2.3 Proximity Limit Switches. UL listed proximity type end-of-travel **[/speed change]** limit switches shall be installed on the miter gate machinery **[as shown on the drawings]**. The proximity switches shall be unshielded **[120VAC][24VDC][24VAC]**, **[25ma, for PLC operation only]** switch rating, one normally open and one normally closed output, NEMA 6P designed for submersion, with stainless steel barrel and housing. Operating range shall be [ ] inches with **[10]**% hysteresis, **[10]**% repeatability, and operating temperature range of **[-10 to 150 deg F][-25 to 70 deg C]**. The cable entrance and wire strands shall be epoxy sealed to protect against the entrance of water into the switch. The switch shall be factory pre-wired using SOOW-A rated cable. The Contractor shall determine the cable length required. The Contractor shall be responsible for adjusting the limit switches for proper operation at the normal machinery end-of-travel position.

2.5.3 Position Transducer. The Contractor shall furnish and install all cable, conductors, conduit and other necessary hardware to wire the **[new][existing]** miter gate position transducers into the new miter gate control system. The transducers shall be wired **[as shown on the drawings]**.

2.5.3.1 Rotating Shaft Encoders. The miter gate position transducers shall be UL listed rotating shaft type for converting the position of the miter gates and shall be a [ ]-turn, electromagnetic, absolute resolver type, capable of immediately returning the correct angular position after a power loss with no manual resetting required. The output of the transmitter shall be directly linearly proportional to the angular position of the rotating machinery. The transmitter shall meet or exceed the following requirements:

(1)	Power Supply Voltage	24 VDC
(2)	Output Signal	4-20 mA (3-wire including power supply)
(3)	Accuracy	0.05 Percent
(4)	Shaft Diameter	**[0.625 inch]**
(5)	Operating Temperature	-20 to 70 deg C

The transmitters shall include the following inherent features as standard equipment:

a. Built-in gas tube lightning and surge protection.
b. Corrosion resistant NEMA 4 housing.
c. Unlimited resolution.

The transmitters shall provide these features and meet these requirements without the need for any encoders, signal conditioners, or other electronics. The signal directly from the transmitter shall be used by the PLC analog input cards (SECTION CEGS 16910) to determine the gate position. All scaling and offsetting shall be accomplished in the PLC programming software. The transmitter 24 VDC power supplies shall be as specified in SECTION 16900-[**2.3.11.2**]. The Contractor shall program the PLC to condition the signal from the miter gate rotating shaft position transducer to produce the correct position of the miter gates through the full range of travel.

2.5.3.2 Hydraulic Cylinder Position Transducers. The position of the miter gates shall be measured using a position tracking system built into the hydraulic cylinder and rod assembly. The transducer shall be furnished as part of the hydraulic system and shall be of the same manufacturer as the hydraulic cylinder. The output of the transducer shall be directly linearly proportional to the extension and retraction of the hydraulic rod. The transducer system shall meet or exceed the following requirements:

(1) Power Supply Voltage	[**24 VDC**]
(2) Output Signal	[**Quadrature encoder**][**Bi-directional Pulse Count**][**4-20ma**]
(3) Accuracy	[**0.1% FS**]
(4) Environmental	NEMA 3R

The hydraulic cylinder position tracking system shall provide these features and meet these requirements without the need for any encoders, signal conditioners, or other electronics. The signal directly from the transmitter shall be used by the PLC high speed counter or analog input cards (SECTION CEGS 16910) to determine the rod position. All scaling and offsetting shall be accomplished in the PLC programming software. The transducer power supplies shall be as specified in SECTION 16900-[**2.3.11.2**]. The Contractor shall program the PLC to condition the signal from the miter gate hydraulic cylinder position tracking transducer to produce the correct position of the miter gates through the full range of travel.

2.6 DAM GATE CONTROLS.

2.6.1 General. The Contractor shall furnish and install all necessary connectors, cables, electronic equipment, electrical devices, and miscellaneous hardware to fulfill the control function specified herein [**and as shown on the drawings**] for the dam [**tainter**] gates. The Contractor shall adjust the length of any manufacturer-supplied cable so that connection points are accessible without splices. Unless specified otherwise, all equipment and installation shall conform to SECTION [**CEGS 16120 – INSULATED WIRE AND CABLE, CEGS 16403 – MOTOR CONTROL CENTERS, SWITCHBOARDS, AND PANELBOARDS, CEGS 16768 – FIBER OPTIC DATA TRANSMISSION SYSTEMS, and CEGS 16792 – WIRE LINE DATA TRANSMISSION SYSTEM**]. The dam gates shall normally be controlled from the IPC computer screens via PLC I/O [**and/or by manual control from pushbuttons on the gate starters**]. The Contractor shall furnish and install all enclosures, control relays, pushbuttons and other hardware [**as indicated on the drawings**] to construct the dam gate control system.

2.6.2 Limit Switches. The Contractor shall furnish and install all cable, conductors, conduit and other necessary hardware to wire the [**new**][**existing**] dam

gate limit switches into the dam gate control system. [**Existing limit switches shall be thoroughly cleaned inside and outside of the limit switch enclosures, contacts cleaned, and actuating mechanism greased. Switches shall be re-tensioned to make proper electrical contact, and the contact areas silver-soldered and sanded smooth to form a good electrical contact surface.**] The limit switches shall be wired [**as shown on the drawings**].

2.6.3 Position Transducer. The Contractor shall furnish and install force balance inclinometer type transducers on each dam gate for the purpose of measuring the gate opening. The inclinometers shall provide an electrical signal [(**4-20 mA**)][(**0-5VDC**)], which is proportional to the sine of the angle of tilt of the gate. The inclinometer output shall be used for remote indication of gate position.

****

Note: For dam gates that move in a linear motion, such as roller type gates, the designer should add to or modify this section to specify a position sensing system similar to that specified for culvert valve position sensing.

****

2.6.3.1 Inclinometers. The dam gate inclinometers shall be UL listed with an angular range of plus or minus [ ] degrees, with self-contained enclosure, +/- 0.2 percent of full range accuracy, and +/- 0.1 percent of full range repeatability.

2.6.3.2 Inclinometer Enclosure. The Contractor shall furnish and install a NEMA 4X stainless steel enclosure for each inclinometer, with interior bottom mounting plate and exterior mounting lugs. The Contractor shall verify all dimensions of the inclinometer and size the inclinometer enclosures accordingly. All conduit connections to the inclinometer enclosure shall be fitted with explosion proof fittings potted with suitable epoxy sealant to prevent the entrance of water into the enclosure.

2.6.3.3 Mounting. The inclinometer enclosure shall be mounted on the top radial strut of the dam gates [**as shown on the drawings**]. The enclosure exterior mounting lugs shall be bolted to the strut. The inclinometer output shall be [**mA**][**VDC**] when the top strut is level, indicating that the inclinometer is measuring an angle of 0 degrees (horizontal). All solder connections shall be potted using waterproof epoxy resin compound.

2.6.3.4 Inclinometer Calibration. The Contractor shall provide calibration sheets for each inclinometer verifying the output signal at 0 degrees (horizontal), plus and minus 10, 20, 30, and 45 degrees, and at extremes of gate travel. The Contractor shall program the PLC to condition the signal from the dam gate inclinometer position transducer to produce the correct opening of the gate (from sill to bottom of gate) through the full range of travel. Gate opening accuracy shall be to the nearest [**tenth**] of a foot.

2.7 WATER LEVEL SENSING SYSTEMS.

2.7.1 General. The upstream, lock chamber, and downstream water levels shall be measured using submersible pressure transmitters installed [**as shown on the drawings**]. The signals from these transmitters shall be routed to PLC I/O racks for manipulation by the PLC ladder logic programming to the appropriate water levels.

2.7.2 Transmitters. The submersible pressure transducers shall be an integral pressure measuring device with permanently encapsulated electronics and sensors, a NEMA 6 rating for permanent submerged installation, molded cable with strain relief cord rated for minimum 100 lbs. breaking strength, pressure reference vent tube (part of cord), and corrosion resistant housing. The pressure transmitters shall meet or exceed the following specifications.

(1) Power	24 VDC @ 8 mA
(2) Output	4 - 20 mA DC

(3) Accuracy	+/- 0.06 percent of full scale
(4) Temperature Range	-20 C to +60 C
(5) Pressure Range	[Designer shall specify] PSI

Exact locations and mounting details of the transmitters shall be [**as shown on the drawings**]. The Contractor shall program the PLC to condition the signal from the water level pressure transmitter to produce the correct water elevation in **[National Geodetic Vertical Datum (NGVD)][river stage]** to the nearest **[.01]** foot through the full range of water level fluctuation.

2.7.3 Power Supplies. Dedicated power supplies shall be provided for the pressure transmitters. The supplies shall operate on 120 VAC, 60 Hz and provide 24 VDC power. Power supplies shall be UL listed, of the enclosed type with 0.1% output voltage regulation, overcurrent and overvoltage protection, minimum operating temperature range of [**32 to 140 deg F**][**0 to 60 deg C**], and minimum 500 VAC isolation input to output, output to ground, and input to ground.

2.7.4 Junction Boxes. The Contractor shall furnish and install junction boxes for the water level sensing system. The junction boxes shall be a minimum 6-inch x 6-inch x 4-inch NEMA 4X with terminal blocks and a replaceable desiccant module with moisture indicator. The junction boxes shall be located [**as shown on the drawings**].

2.8 ADJUSTABLE FREQUENCY DRIVES.

2.8.1 General. The Contractor shall provide Adjustable Frequency Drives (AFD) for lock operating machinery [**as shown on the drawings**]. The AFD shall provide proper torque, acceleration, braking, and speed control for the motors that drive the systems. The AFDs shall work in conjunction with the PLC system network (SECTION CEGS 16910) to properly perform all control operations as specified herein.

2.8.2 Compatibility. Because proper operation of the AFDs and the associated operating machinery relies on the position tracking and speed control logic within the PLC system, the AFDs shall be of the same manufacturer as the PLC control system specified in **[SECTION 16910 – Programmable Logic Controller]**.

2.8.3 A.C. Drive Engineer. The Contractor shall retain the services of a competent A.C. drive specialist, herein A.C. Drive Engineer, to perform or supervise all procuring, manufacturing, installing, wiring, and programming of the AFD systems specified herein and performing motor tests as required. The A.C. Drive Engineer shall be an employee of the drive manufacturer and shall have experience on at least three other projects interfacing the same drives and the same PLC equipment as proposed for use on this project. The A.C. Drive Engineer shall be completely responsible for providing a correctly operating drive system for the lock machinery motors.

****

Note: The following modes of operation have been written for a vertical lift gate or miter gate application. They may be deleted or revised for operation of other machinery such as bulkhead hoists or lift bridges.

****

2.8.4 Operation of Motor Drive Systems. The AFDs shall be capable of providing the following modes of operation. The Contractor shall be responsible for insuring that the drive and PLC position tracking systems are properly coordinated to produce a smooth and uniform operation of all machinery for each piece of equipment. Normal operation of all machinery will be initiated by a command from the IPCs (SECTION CEGS 16920) transmitted to the AFDs via the PLC network (SECTION CEGS 16910).

2.8.4.1 Normal Operation. Normal operation will require the **[liftgate leaves to raise and lower][miter gate leaves to open and close]** between limits which are adjustable in the PLC software. At these times the water differential against the gates will be zero. The motors will accelerate from zero speed to rated RPM while producing rated torque at all speeds to smoothly bring the gate from rest to proper speed and then decelerate in the same fashion bringing the gate to a stop. In this mode the motor will be operating at [ ] RPM. **[During normal operation of the gate leaves uneven loading will occur on the hoisting machinery sets which will cause the gate to skew. The position tracking system will allow the PLC to know the elevation of each side of the gate leaf. The PLC shall use this information to feed a relative speed reference signal to each AFD (on one leaf) to correct the skewing of the gate automatically. In this fashion, the two AFDs on the same gate leaf shall keep the gate level.][During normal operation uneven loading will occur on the miter gate leaves causing them to travel at different relative speeds. The position tracking system will allow the PLC to know the position of each leaf. The PLC shall use this information to feed a relative speed reference signal to the AFD on each to correct relative difference in gate position between sides. In this fashion, the two AFDs on the same set of miter gate leafs shall bring the gates closed together.]**

2.8.4.2 **[Ice Flushing Operation. In the ice flushing mode, the liftgate will be lowered against a water level differential to a maximum of [ ] feet to allow the passage of ice over the top of the gates. This will require the maximum rated torque of the motor and drive. In this mode the motor will be operating at [ ] RPMs.]**

2.8.4.3 Skew Correction. In the event that the relative elevations of each side of the **[gate][bulkhead][bridge]** reach an absolute difference of more than [ ] foot, the PLC shall stop the AFDs and the programming shall allow one hoist motor to operate until the skew is zero. This is intended to be a rarely used feature as the skew shall be kept to a minimum as described above.

2.8.5 Software. The Contractor shall be responsible for programming the PLC with the proper software necessary to operate the lock machinery AFDs. This shall include programming to convert the signals from the position tracking system from an analog signal to an NGVD elevation. In addition the Contractor shall be responsible for programming all control features necessary to properly operate the AFDs. This programming shall be accomplished through the PLC network.

2.8.6 Drive Description. The Contractor shall furnish and install **[wall-mounted][free-standing]** pre-engineered A.C. Adjustable Frequency Drives containing all of the features as defined herein. The drives shall be provided in number and location **[as shown on the drawings]**.

2.8.6.1 Circuit Breaker. The AFDs shall be designed with a properly sized and rated circuit breaker, with all the features necessary to protect the drive and motor circuit. The circuit breaker shall be as recommended by the drive manufacturer for that drive. It shall be part of the standard equipment normally furnished with the type of pre-engineered AFD sizes proposed for use under this contract. The circuit breaker operating handle shall be interlocked with the enclosure door latch hardware to prevent opening the door with the circuit breaker energized.

2.8.6.2 Fuses. The AFDs shall have fuses to protect the DC bus, thyristors, and other parts of the drive. The fuses shall be standard equipment as normally furnished by the AFD manufacturer with the unit.

2.8.6.3 Enclosure. The AFDs with all features and accessories as specified herein, and as required for proper operation, shall be contained in **[NEMA 12][NEMA 3R]** enclosures. Enclosures shall be the standard **[wall mount][free-standing]** type normally furnished by the drive manufacturer for that drive. The enclosures shall have sufficient ventilation as recommended by the manufacturer and pro-

visions for conduit entry from top and bottom. The keypad controls shall be mounted on the outside of the enclosure.

****
Note: The following paragraphs describe the inverter itself. Technology in this area changes rapidly so the designer should check with manufacturers to insure that the latest technology and features are specified.
****

2.8.6.4 Performance Requirements. The lock machinery drive systems shall be fully digital, microprocessor based, Pulse Width Modulated (PWM) A.C., **[constant torque][variable torque]** Adjustable Frequency Drives. The AFDs shall incorporate a **[16-bit]** microprocessor system to control all logic functions including the pulse width modulation (PWM) switching of the power transistors. The power transistors shall be Insulated Gate Bipolar Transistors (IGBT). The AFD units shall be pre-engineered by one manufacturer and shall be a standard off-the-shelf drive as normally provided by that manufacturer. The AFDs shall meet the applicable requirements of UL 508C, and NEMA ICS 3.1. The drives shall meet or exceed the following requirements:

(1)	Input Voltage	460±15% AC, 60 Hz
(2)	Displacement Power Factor	Between 1.0 and .95 Lagging
(3)	Operating Ambient Temp	20°F - 105°F
(4)	Efficiency	96% at rated speed
(5)	Constant Torque Rating	150%
(6)	Acceleration Time	0.1 to 400 seconds
(7)	Output Frequency Range	1.5 to 60 Hz

The AFDs shall incorporate the following features:

(1) D.C. Braking

(2) Isolated Remote Speed Reference Signal (From PLC Network)

(3) Digital Keypad Programmer (Mounted on Exterior)

(4) JOG Forward and JOG Reverse keypad input

(5) Manual control interface

(6) Man-Off-PLC selector switch

(7) Dynamic Braking

2.8.6.5 PLC Communications. The AFDs shall be controlled by the PLC network system. Each drive shall be connected to the network **[as shown on drawings]**. Communications between the PLC and each drive shall be a **[multiplexed serial link][Ethernet]** providing all normal raise and lower, ice flush raise and lower, and skew correction raise and lower signals, as well as speed reference and operating feedback signals to the PLC. The PLC system shall be capable of reading the following information (registers) from the VFD controller:

(1) Drive Ready

(2) Direction

(3) Motor Running

(4) Dynamic Braking

(5) Fast Stop

(6) Jog

(7) Deceleration time

(8) Acceleration time

(9) Motor Speed

(10) Speed reference

(11) Output frequency

(12) Output current

(13) All faults and fault parameter values

(14) Auto/Manual

(15) Motor torque

2.8.6.6 Re-generation. When the machinery is **[lowering][coasting]** or decelerating, significant re-generation of electrical power is expected. The AFDs shall have dynamic braking resistors of sufficient size to protect the drive.

****

Note: The Designer should calculate the amount of power that must be dissipated through the dynamic braking resistor. All applications will require some dynamic braking. Hoisting/lowering applications will require oversized dynamic braking resistors. This effort could also be given to the contractor's AC Drive Engineer.

****

2.8.6.7 Built-in Diagnostics. The AFD controllers shall have built-in troubleshooting diagnostics and fault circuits that provide, as a minimum, indication of the following faults:

(1) Power Loss

(2) Under Voltage

(3) Over Voltage

(4) Motor Stall

(5) Motor Overload

(6) Over Temperature

(7) Ground Fault

(8) Microprocessor Fault

(9) PLC Communication Failure

(10) Dynamic Braking Resistor Failure

(11) Pre-Charge Capacitor Failure

2.8.6.8 Manual-Off-PLC Feature. The AFDs shall be equipped with a Hand-Off-Auto type selector switch. In the MANUAL (HAND) position the drive shall operate using the JOG FORWARD and JOG REVERSE buttons on the drive key-

pad controller or the hardwired manual controls interface. Speed, acceleration time, deceleration time, and max/min speeds, shall default to parameters set by the keypad controllers. In the OFF position the drive will not operate. In the PLC (AUTO) position the drive will be completely controlled by the PLC over the PLC network. The PLC shall set, through logic, the speed, accel/decel, and min/max speed.

2.8.6.9 **[Manual Bypass. The AFDs shall be designed with an inherent bypass feature, which will allow across-the-line starting of the motors in the event of a drive failure. The feature shall be enabled by a selector switch on the drive unit. The bypass feature shall be interlocked with the normal drive output so that both cannot be enabled at once.]**

2.8.6.10 Run Contactor. The AFDs shall be equipped with a run contactor that is energized upon operation of the drive. The run contactor shall be used to interlock the drives with the machinery brakes.

2.8.6.11 Machinery Brake Contactor. The AFDs shall be designed with controls for releasing and setting the machinery brake contactor. The brakes shall be released upon energization of the motor and set when the motor has decelerated to zero speed.

2.8.7 Installation. The AFDs shall be installed in the locations [**as shown on the drawings**]. Installation shall be in accordance with the Manufacturer's recommendations and shall be supervised by the A.C. Drive Engineer.

2.8.8 Programming. The A.C. Drive Engineer shall be responsible for programming all of the parameters inherent to the AFDs. Programming shall be by means of the externally mounted keypad. The Contractor's System Integrator (Section CEGS 16910) shall be responsible for accomplishing all PLC programming necessary to incorporate proper operation and feedback of the drive systems into the PLC control network.

2.8.9 Isolation Transformers. The Contractor shall furnish one (1) isolation transformer for each drive. The isolation transformers shall be 460V - 460V of suitable KVA for the drives that it will serve, and of sufficient K-factor rating to prevent the introduction of DC switching harmonics into the rest of the project power system. The isolation transformers shall be specified by the A.C. Drive Engineer. The isolation transformers shall be located [**as shown on the drawings**].

2.9 MISCELLANEOUS CONTROL SYSTEMS.

2.9.1 General. The Contractor shall furnish and install all necessary electrical and electronic equipment, devices, conduit, cable, conductors, and other hardware necessary to complete the control systems as specified herein [**and shown on the drawings**]. Unless noted otherwise, all equipment and installation shall conform to SECTION [**CEGS 16120 – INSULATED WIRE AND CABLE, CEGS 16403 – MOTOR CONTROL CENTERS, SWITCHBOARDS, AND PANELBOARDS, CEGS 16768 – FIBER OPTIC DATA TRANSMISSION SYSTEMS, and CEGS 16792 – WIRE LINE DATA TRANSMISSION SYSTEM**].

2.9.2 Photoelectric Switches.

****

Photoelectric switch technology varies significantly by application, and this type of switch has various application possibilities at a lock and dam project. The designer shall research the intended application and fill in the areas below to form the optimal specification for each particular application. The same project may require different types of switches for each application.

****

UL listed Photoelectric type switches shall be installed in areas [**as shown on the drawings**]. The photoelectric switches shall use the [**transmitted beam**][**retro-reflective**][**diffuse**] technology for sensing objects within the operating range. The transmitter shall operate on [**120 VAC**] and the detector shall be rated for load current of [**5A, 120VAC (Relay)**][**25ma, 0-120V AC/DC (solid state)**]. Both shall be contained in a [**NEMA 13**] corrosion resistant housing. The transmitter and detector shall be spectrally matched for optimum performance with the technology specified using infrared light and shall have a minimum Operating Margin of 20X at 150 feet.

****

Note: The designer shall use this section to specify purchasing and installation details for support control systems such as traffic lights, bubbler systems, pleasure craft signals, signal horns, ..etc.

****

2.10 SPARE PARTS. The following spare parts shall be provided in quantity as specified below.

****

Note: Spare part quantities shown here are for guidance only. The designer should consider the project, the location, the projected type and amount of usage and determine appropriate quantities for the spare parts.

****

1. [**Three (3)**][**quantity**] I/O cab power supplies
2. [**One (1)**][**quantity**] I/O rack enclosure air-conditioning unit;
3. [**Four (4)**][**quantity**] miter gate [**magnetic**][**proximity**] limit switches with magnets;
4. [**Two (2)**][**quantity**] rotating shaft miter gate position encoders;
5. [**Two (2)**][**quantity**] miter gate overtravel limit switches;
6. [**Four (4)**][**quantity**] culvert valve [**magnetic**][**proximity**] limit switches with magnets;
7. [**Two (2)**][**quantity**] rotating shaft culvert valve position encoders;
8. [**Two (2)**][**quantity**] culvert valve overtravel limit switches;
9. [**Three (3)**][**quantity**] dam tainter gate position inclinometers;
10. [**Two (2)**][**quantity**] water level sensing system power supplies;
11. [**Three (3)**][**quantity**] water level pressure transducers;
12. [[**Three (3)**][**quantity**] AFD circuit breakers
13. [**Ten (10)**][**quantity**] AFD fuses for each different size fuse
14. [**Three (3)**][**quantity**] of each board used in the AFDs
15. [**One (1)**][**quantity**] AFD keypad programmer
16. [**Six (6)**][**quantity**] Sets of each type of AFD output transistor
17. [**One (1)**][**quantity**] Complete AFD unit for each type and size

****

Note: The designer should specify any spare parts for miscellaneous control systems here.

****

PART 3 - EXECUTION

3.1 CONTROL AND INSTRUMENTATION CABLE INSTALLATION.

3.1.1 General. Unless specified otherwise herein, all cable installation shall be in accordance with SECTION [CEGS 16120 – INSULATED WIRE AND CABLE, CEGS 16768 – FIBER OPTIC DATA TRANSMISSION SYSTEMS, and CEGS 16792 – WIRE LINE DATA TRANSMISSION SYSTEM]. All cable not installed in cable tray or duct shall be installed in RGS conduit sized in accordance with the National Electric Code.

3.1.2 Pulling of Wires and Cables. Wires and cables shall be pulled in accordance with SECTION [**CEGS 16120 – INSULATED WIRE AND CABLE**].

3.1.3 Splicing. Control and instrumentation cables shall not be spliced.

3.1.4 Cable and Conductor Identification. All cables and conductors shall be labeled, tagged or otherwise identified in accordance with SECTION [**CEGS 16120 – INSULATED WIRE AND CABLE**], and [**as delineated on the drawings**].

3.2 CONTROL CONSOLE INSTALLATION.

The Contractor shall install the control consoles in accordance with the recommendations made by the Console Manufacturer and [**as shown on the drawings**]. The Contractor shall be responsible for the complete and proper installation of the control console and all appurtenances contained within.

3.3 REMOTE I/O RACK ENCLOSURE INSTALLATION.

The Remote I/O Racks shall be installed [**as shown on the drawings, and**] in accordance with the National Electric Code, NFPA 70.

3.4 INSTALLATION OF LOCK AND DAM CONTROL SYSTEMS.

The Contractor shall install the control systems for the lock and dam equipment as specified herein [**and in accordance with the drawings**]. The Contractor shall be completely responsible for the correct operation of all control systems.

3.5 TRAINING. The Contractor shall provide a minimum of three 8-hour training sessions at the job site for operating personnel. In addition, during the final adjustments and the final acceptance tests, the Contractor shall instruct and demonstrate to designated Government personnel all of the operation, preventive maintenance, adjustment, and test procedures for all equipment specified herein. Lock maintenance personnel shall also be permitted to observe the various maintenance procedures performed on the equipment by the Contractor during the guarantee and service periods.

3.5.1 AFD Training. The Contractor shall provide training for the Adjustable Frequency Drive Systems as outlined below. The Contractor shall notify the Contracting Officer 10 days prior to each training session.

3.5.1.1 Off-site Installation and Programming. The A.C. Drive Engineer shall provide 3 eight-hour off-site training sessions that will cover detailed installation and programming of the AFDs. The A.C. Drive Engineer shall provide training manuals and instructional bulletins to be used during the training. The training shall be tailored to the AFD types and sizes that are proposed for this system. Similar drives shall be used during the sessions for "hands on" training. All ad-

justments, parameters, operational modes of the drives shall be covered in the training.

3.5.1.2 On-Site Operation. After completion of the testing specified in paragraph 16900-3.5.1.1 to the satisfaction of the Contracting Officer, the A.C. Drive Engineer shall provide 1 eight-hour on site operational training session on the AFDs. This training shall include operation in the different modes on each AFD, and programming of the adjustable parameters through the PLC system. The Contractor's system Integrator (SECTION 16910) shall be present for this training and cover in detail the PLC communications to the drive.

3.5.1.3 Documentation. The A.C. Drive Engineer shall prepare a complete set of documentation on the AFDs. The documentation shall include a complete description of each programmable parameter, the recommended (initial) setting of each parameter, and optional settings with complete description of the performance changes these options have. The documentation shall include all as-built drawings of the equipment. All wiring connections shall be clearly shown. The documentation shall also include all manufacturer's operation and maintenance manuals with addendums tailored specifically to the operation and maintenance of the AFDs used in this installation. The documentation shall be bound in a binder with cover sheet and reference tabs and submitted in triplicate within 20 days after acceptance of the installed lock AFD systems by the Contracting Officer.

3.6 OPERATIONS, MAINTENANCE, AND INSTALLATION MANUALS. The contractor shall provide complete documentation for the operation, maintenance, and installation of all pushbuttons, limit switches, transducers, power supplies, switches, pilot lights, and all equipment specified in this section. If possible the information should be provided BOTH in hardbound volumes as well as on CD-ROM.

3.7 TESTING.

3.7.1 All equipment furnished under this section shall be tested as specified here and in other sections. All tests shall be witnessed by the Contracting Officer.

3.7.2 Culvert Valve Control Systems. Each culvert valve shall be operated a minimum of ten complete cycles without the occurrence of problems. The Contractor shall provide equipment and personnel as necessary to operate the culvert valves during testing. The Contracting Officer may, at his option, vary the test procedure to witness intermediate stopping and starting of the valves. This shall be done without additional cost or delays to the Government. Correct operation shall be demonstrated for all of the operating cycles constituting the acceptance testing. Incorrect operation shall be grounds for complete re-testing. Correct operation shall include, but not be limited to:

1) The valves properly starting and stopping on the limits.

2) Valve speed changes at appropriate times and/or water levels.

3) Complete operation of all limit switches.

4) Correct indication of culvert valve position and status of limit switches on all IPC control screens.

5) Operation of normal and emergency stops.

[6) Correct operation of the any special filling and emptying sequences.]

7) Correct operation of all machinery, motors, brakes, and disconnect switches.

8) Correct operation of water level interlocks and interlock bypass features.

3.7.3 Miter Gate Control Systems. Each miter gate shall be operated a minimum of ten complete cycles without the occurrence of problems. The Contractor shall provide equipment and personnel as necessary to operate the miter gates during testing. The Contracting Officer may, at his option, vary the test procedure to witness intermediate stopping and starting of the miter gates. This shall be done without additional cost or delays to the Government. Correct operation shall be demonstrated for all of the operating cycles constituting the acceptance testing. Incorrect operation shall be grounds for complete re-testing. Correct operation shall include, but not be limited to:

1) The gates properly starting and stopping on the limits.

2) Gate speed changes at appropriate times and/or water levels.

3) Complete operation of all limit switches.

4) Correct indication of miter gate position and status of limit switches on all IPC control screens.

5) Operation of normal and emergency stops.

[6) Correct operation of any ice restriction or other special operating modes.]

7) Correct operation of all machinery, motors, brakes, and disconnect switches.

8) Correct operation of water level interlocks and interlock bypass features.

3.7.4 Dam Gate Control Systems. The dam gates shall be operated in the presence of the Contracting Officer and under the direction of the Lockmaster only. The Contracting Officer may vary test procedures due to river conditions. The Contracting Officer shall make a final determination of the test procedures on site, after taking into account river conditions. Each dam gate shall be operated a minimum of five complete cycles without the occurrence of problems. The Contractor shall provide equipment and personnel as necessary to operate the dam gates during testing. The Contracting Officer may, at his option, vary the test procedure to witness intermediate stopping and starting of the gates. This shall be done without additional cost or delay to the Government. Correct operation shall be demonstrated for all of the operating cycles constituting the acceptance testing. Incorrect operation shall be grounds for complete re-testing. Correct operation shall include, but not be limited to:

1) The gates properly starting and stopping on the limits.

2) Complete operation of all limit switches.

3) Correct indication of gate opening and status of limit switches on all IPC control screens.

4) Operation of normal and emergency stops.

[5) Correct operation of any alarm conditions, if testable, such as gate obstruction or pool loss alarms.]

6) Correct operation of all machinery, motors, brakes, and disconnect switches.

7) Correct operation of incremental gate raise feature.

3.7.5 Adjustable Frequency Drive Systems. The Contractor shall operate the adjustable frequency drive systems in all modes in the presence of the Contracting Officer for a period of 8 hours. During this time the Contracting Officer shall determine the sequence and frequency of operation of each drive system. All operating modes and alarms shall be tested. If the Contracting Officer is not satisfied that the intent of these specifications has been fulfilled, the Contractor shall

correct all deficiencies and provide a complete retest at no additional cost to the Government.

3.7.6 Miscellaneous Control Systems. All miscellaneous control systems as specified herein **[or shown on the drawings]** shall be demonstrated to the Contracting Officer to be in correct operating condition. Any problem incurred during testing of the miscellaneous control systems shall constitute complete re-testing after the Contractor has corrected any problems.

--End of Section--

****

SECTION 16910

PROGRAMMABLE LOGIC CONTROLLER

****

Note: This guide specification covers the requirements for procurement and installation of electrical and electronic devices provided with the Programmable Logic Controller System. This guide specification is intended to cover both new lock construction as well as rehabilitation work. With some editing this guide specification can be used for other civil works projects as well. When using this guide specification the designer will be required to include portions of CEGS 16120 – INSULATED WIRE AND CABLE, CEGS 16403 – MOTOR CONTROL CENTERS, SWITCHBOARDS, AND PANELBOARDS, CEGS 16768 – FIBER OPTIC DATA TRANSMISSION SYSTEMS, CEGS 16792 – WIRE LINE DATA TRANSMISSION SYSTEM, CEGS 16794 – COAXIAL CABLE DATA TRANSMISSION MEDIA, and CEGS 16900 – INSTUMENTATION AND CONTROL. This document specification is to be used in the preparation of project specifications in accordance with ER 1110-345-700 for military construction and in accordance with ER 1110-2-1201 for civil works construction.

****

PART 1 - GENERAL

1.1 REFERENCES.

****

Note: Issue date of references included in project specifications need not be more current than provided by the latest change (Notice) to this guide specification.

****

The publications listed below form a part of this specification to the extent indicated by the references thereto. The publications are referred to in the text by basic designation only.

Electronic Industries Alliance (EIA).

422-B	(1994) Electrical Characteristics of Balanced Voltage Digital Interface Circuits

Institute of Electrical & Electronics Engineers (IEEE).

C37.90.1	(1989; R 1994) Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems
802.3	(1998) Information Technology - Local and Metropolitan Area Networks - Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specification

International Electrotechnical Commission (IEC).

1131-3	Rating and Testing for Contactors

National Electrical Manufacturers Association (NEMA).

ICS 3	(1993) Industrial Control and Systems Factory Built Assemblies

National Fire Protection Agency (NFPA).

No. 70	(1999) National Electrical Code

Underwriters Laboratory (UL).

508	(1993; Rev thru 1997) Industrial Control Equipment
NRAQ	(1999) List of Approved Programmable Logic Controller Manufacturers

1.2 SYSTEM DESCRIPTION

****

Note: It is recommended that the designer prepare detailed engineered plans to accompany this specification. Plans should show all significant arrangements, sizes, capacities, quantities, wiring and all other details and information necessary to convey to a contractor the intention of the design to facilitate successful bidding and construction of the Programmable Logic Controller System.

****

This section addresses the requirements for the Programmable Logic Controller (PLC) system, as defined in NEMA Standard ICS 3, Part 3-304.01, which shall control the project equipment. The Contractor shall furnish all plant, labor, equipment, material, and perform all operations to install, test, and demonstrate the correctly working PLC system as functionally defined herein [**and as shown on the drawings**]. The Contractor shall use a System Integrator or an industrial controls firm as the PLC system supplier. Unless otherwise noted herein, all equipment provided under this specification shall be installed in accordance with SECTION [**CEGS 16120 – INSULATED WIRE AND CABLE, CEGS 16403 – MOTOR CONTROL CENTERS, SWITCHBOARDS, AND PANELBOARDS, CEGS 16768 – FIBER OPTIC DATA TRANSMISSION SYSTEMS, CEGS 16792 – WIRE LINE DATA TRANSMISSION SYSTEM, and CEGS 16794 – COAXIAL CABLE DATA TRANSMISSION MEDIA**] - and SECTION CEGS 16900 - CONTROL AND INSTRUMENTATION. The scope of this project includes connecting different vendor's equipment to a common communication network. It shall be the responsibility of the Contractor to provide system integration services and to furnish and install all labor, materials, hardware, software, testing and training, as required, to provide a fully functional Programmable Logic Controller System as follows:

1) A turnkey PLC system including processor, remote input/output (I/O) racks and cards, controllers, [**other PLC-controlled devices such as panelboards and Adjustable Frequency Drives,**] cabling, and fiber optic and network interface modules.

2) Communication between devices as necessary, including software.

3) Integration of the Industrial Personal Computers (IPC, specified in SECTION CEGS 16920) at various locations to program the PLC processor and provide a Graphical User Interface (GUI) for operation of the project.

4) Capability of controlling the lock and dam gates, controlling other devices, starting/stopping the various gate and valve motor controllers, providing the user with gate position data, and other functions as specified herein **[and as shown on the drawings]**.

1.3 SUBMITTALS

****

Note: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.

Indicate submittal classification in the blank space using "GA" when the submittal requires Government approval or "FIO" when the submittal is for information only. It is a good idea to require that all of the PLC system shop drawings be submitted together for approval. This allows the designer to review the whole system for compatibility and integration. It is also a good idea to require that portions of the IPC submittal (Section 16920) and/or portions of Instrumentation and Control (Section 16900) be submitted with the PLC shop drawings to insure overall integration and compatibility of the entire computerized control system.

****

Government Approval is required for submittals with a "GA" designation; submittals having an "FIO" designation are for information only. The following shall be submitted in accordance with Section 1330 SUBMITTAL PROCEDURES:

[SD-16910-01 PLC System Components.
Processor (GA)
Remote Racks (GA)
Input/Output Communication cards (GA)
Digital Input and Output cards (GA)
Analog Input and Output cards (GA)
Network Communication cards (GA)
Power Supplies (GA)
Cables and Connectors (GA)
Fiber Optic Converter modules (GA)
System Block Diagram (GA)
IEC Control Program Software (GA)
Communication Data Line Surge Protectors (GA)

SD-16910-02 System Integrator Qualifications
Qualifications (GA)
Experience (GA)
References (GA)

SD-16910-03 Programming
Input/Output Address List (GA)
IEC 1131 Control Program (GA)

SD-16910-04 Schedules.
Programmable Logic Controller System Training (GA)
Programmable Logic Controller System Testing (GA)

SD-16910-05 Manuals and Literature.
Manuals and Literature for all PLC equipment (FIO)]

1.4 PROJECT/SITE CONDITIONS

1.4.1 Environmental Requirements

The environment into which the electrical equipment will be installed is an outdoor facility subject to 100 percent humidity and temperature variations between **[Specify]** and **[Specify]** degrees [F][C]. The Contractor shall ensure that during installation all equipment is properly handled and stored so that it will not be adversely affected by the above conditions. The Contractor shall also ensure that the final installation of equipment meets the environmental requirements of the manufacturer.

1.4.2 Existing Conditions

****

Note: The designer shall use this section to delineate any special existing conditions that affect the work as specified herein. This is a particularly important section for contracts that include rehabilitation of lock control systems. In some cases existing machinery or electrical distribution systems will be reused by the contractor. These items should be explained in this part of the specification using sufficient detail to fully convey existing conditions and requirements necessary to bid and complete the contract work.

****

1.5 DELIVERY, STORAGE, AND HANDLING

Equipment specified in this section, comprised of electrical and electronic components, shall be scheduled for shipment to arrive on the job site no more than [ ] days

****

Note: The amount of time electronic equipment can be stored at the job site is specified to preclude prolonged storage and possible obsolescence of some equipment. Large construction contracts can have durations of several years and some electronic equipment can go through revised releases during that time. The designer should be careful to allow enough lead-time not to effect the construction schedule but not excessive time. Sixty days is a good starting point. The designer should refine this for each project and the equipment specified.

****

prior to its scheduled installation date. Upon delivery at the work site, the Contractor shall store all Programmable Logic Controller equipment in areas **[as designated on the drawings][as directed by the Contracting Officer]**. The conditions under which any equipment or materials are to be stored shall be in accordance with the PLC manufacturer's recommendations and with the best standard practices to ensure that all equipment and materials will be in pristine condition at the time of installation. The Contractor shall familiarize itself with regard to the location of all other equipment, materials, and conditions that may affect the electrical work so as to minimize any interference with other installations or to subject any items to detrimental conditions. The exact storage location of all electrical and electronic items shall be subject to the approval of the Contracting Officer.

1.6 STANDARD PRODUCTS

Unless otherwise approved by the Contracting Officer, the materials and equipment to be furnished under this specification shall be standard products of manufacturers regularly engaged in the production of such equipment and shall be the manufacturer's latest standard design.

****

Note: Technology changes rapidly in the programmable logic controller area. The designer shall make manufacturer surveys to ensure that all equipment is of the latest technology incorporating the relevant latest features.

****

Items of equipment shall be of the same product line as equipment that has been in satisfactory use at least two years prior to bid opening. Like equipment for similar service shall be of the same manufacturer, and when of the same size and rating shall be interchangeable. Equipment shall be supported by a service organization that is, in the opinion of the Contracting Officer, reasonably convenient to the site.

1.7 GENERAL ARRANGEMENTS

The general arrangements and approximate locations of the electrical equipment, conduit and wiring connections shall be [**as indicated on the drawings.**] The Contractor may, however, subject to the approval of the Contracting Officer, modify the layout [**indicated on the drawings and/or**] specified herein, to more readily conform to the space available and to the equipment proposed for use. Should the approved electrical equipment furnished be of a different size than indicated, the Contractor at his own expense shall make the necessary adjustments to the branch circuit wiring (8 AWG and smaller), disconnecting devices, branch-circuit protection, component wiring, component installation, I/O rack addressing, PLC programming, PLC component quantities, and space requirements to accommodate the equipment actually installed.

1.8 QUALIFICATIONS

A System Integrator shall be used by the Contractor to furnish and install the PLC system. This firm will be referred to as the "Contractor's System Integrator"; the same firm as specified in Section 16900 and 16920. The Contractor's System Integrator shall be familiar with all hardware and software supplied under this specification section. The Contractor's System Integrator shall show evidence that it has previously integrated the specified hardware and software identical to that intended to be used for this job. The actual PLC manufacturer shall also show satisfactory evidence that they maintain a fully equipped service organization capable of furnishing, within 24 hours, adequate inspection and service for this system, including standard replacement parts. All work shall be performed in a skillful and workmanlike manner in accordance with the best modern shop practice for the manufacture of finished products of a nature similar to those covered by these specifications, and shall be performed by mechanics especially skilled for each kind of work and under competent supervision and direction. All materials and equipment shall be installed in accordance with recommendations of the manufacturer as approved by the Contracting Officer.

1.9 SEQUENCING AND SCHEDULING

****

Note: This paragraph includes any special sequencing or scheduling of work unique to the project. Rehabilitation of existing lock control systems often will require special sequences and schedules and these should be spelled out in sufficient detail to convey the importance to the Contractor. Lock closure times and other limitations such as requirements for back-up generator sets or other temporary power and/or control systems should be included here as technical requirements necessary for a Contractor to bid and construct the project.

****

1.10 WARRANTY

All equipment and material installed under this section shall be warranted to be free of defects, in workmanship and material for a minimum of one year after acceptance by the Contracting Officer. The Contractor shall make written transfer of all manufacturer's warranties to the Government upon acceptance of the work by the Contracting Officer.

1.11 CODE COMPLIANCE

All work, specified herein [**or shown on the drawings**], shall conform to the applicable rules of NFPA Code No. 70-99, The National Electric Code, and ANSI C2, The National Electrical Safety Code.

PART 2 - PRODUCTS

2.1 Programmable Logic Controller System Equipment.

****

Note: If the designer does not intend to use a section for general electrical requirements including wire and cable, appropriate portions of CEGS 16120 WIRE AND CABLE will have to be incorporated here.

****

2.1.1 General. All components as specified herein shall be manufactured or supported by the PLC manufacturer for use on this type of system. In addition, any peripheral or support components that are available from the PLC manufacturer shall be provided as such. The manufacturer of the PLC system shall be on the UL NRAQ List of Approved Programmable Logic Controller Manufacturers. Unless otherwise specified, the power supply to all equipment shall be 120 volts, 60 Hz, single phase. The Contractor shall be responsible for distribution of power between enclosures, consoles, remote devices, and other components of the system. Power distribution hardware shall include cables and branch circuit overcurrent protection installed in accordance with SECTION [**CEGS 16120 – INSULATED WIRE AND CABLE, and CEGS 16403 – MOTOR CONTROL CENTERS, SWITCHBOARDS, AND PANELBOARDS**] and NFPA 70-99, The National Electric Code. All components supplied with the PLC system shall carry a UL listing and shall meet the following requirements:

(1) All power supplies required by equipment other than that provided by the PLC manufacturer, shall be an integral or dedicated part of the equipment furnished. Internal power supplies shall be regulated, current-limiting, and self-protected.

(2) All equipment furnished hereunder shall meet all Surge Withstand Capability (SWC) tests as defined in ANSI C37.90.1 without damage to the equipment.

(3) All equipment furnished shall be capable of tolerating and operating through a power interruption of 8 milliseconds or less without interruption of normal operation.

(4) All equipment supplied under these specifications shall be designed to prevent the generation of surges into the power source during normal operation.

2.1.2 PLC Processor Module.

2.1.2.1 General. The PLC System Processor shall be a rack-mounted module containing the memory, processing, timing, and scanning circuits necessary for examining the status of the inputs and outputs, addressing the memory, performing integer and floating point math operations, trigonometric functions, solving the programmed ladder and IEC control logic, executing the proper I/O functions, and providing self-diagnostics.

2.1.2.2 Memory. The processor shall employ a minimum of [ ] Kbytes [**The designer should adjust this according to project needs keeping in regard the need for future expansion**] of solid-state Random Access Memory (RAM) for operation with on-board batteries for memory retention in the event of power failure or shut down. The battery backup shall retain all programmed logic, system definitions, program labels, and user comments with no external source of power applied for a minimum period of six (6) months.

2.1.2.3 Security. The processor shall be equipped with a security feature, which shall provide, as a minimum, the following functions. One mode shall cause the processor to halt the execution of the programmed ladder logic and allow programming changes to be made. In a second mode the processor shall continue to execute the programmed ladder logic, but prohibit any programming alterations. The third mode shall allow processor execution of the programmed ladder logic and on-line programming alterations. This feature will vary from manufacturer to manufacturer, and the Government will consider alternate designs provided that the processor has inherent safety and security features similar in functional nature to these.

2.1.2.4 Performance. The processor shall be capable of being programmed directly from an IEC 1131.3 compliant software package by means of a personal computer and software as specified in SECTION 16920 – Industrial Personal Computers. The processor shall be capable of, but not limited to, performing the following operations or functions:

(1) Input, output, and internal register status display

(2) Timer and counter functions

(3) Math operations, integer and floating point

(4) Advanced math, trigonometry, Boolean operations

(5) Data comparisons and conditionals

(6) Data transfers, including block transfers

(7) Shift register and sequencer operations

(8) Execution of all five IEC 1131-3 programming languages

(9) Energizing outputs based on above operations and functions contained in the ladder logic. This includes latchable and unlatchable outputs.

The processor shall have a program scan time of not more than one millisecond (ms) per Kword (typical) regardless of the type of programming. The processor shall have, as a minimum, an I/O capacity of **[Designer to specify the number of I/O points]** points and **[Designer to specify]** storage registers. Because specifications vary greatly by manufacturer, the Contractor shall ensure that the supplied processor meets the I/O requirements as specified herein **[and as shown on the drawings]**.

The processor shall be capable of performing an orderly shutdown in the event of an AC power failure and shall restart automatically after power is returned. All PLC outputs shall be disabled so that all PLC-controlled machinery stops movement and other PLC-controlled equipment returns to a prescribed neutral state when the PLC shuts down. Machinery shall not resume operation until re-initiated by an operator.

2.1.2.5 Error Detection. The processor shall be capable of detecting PLC malfunctions including, but not limited to, failure of clock circuits, memory data, decision logic, program counter, I/O circuits, and communications. In the event a malfunction is detected, the processor shall return all specified output circuits to their initial startup status but shall continue execution of the program. The PLC shall be equipped with troubleshooting aids in the form of indicator lights to assist in pinpointing malfunctions in the PLC system. These lights shall indicate, at minimum, the run/halt status of the processor, communication status of all channels, processor error number, remote rack error number, and “forced” bit conditions. The processor shall be capable of providing an alarm when any one of the redundant communication cables fails. At such a time the system shall automatically revert to the good communication cable without the loss of control data.

2.1.2.6 Communications. The processor shall be equipped with an Ethernet port/card to provide a high-speed connection to the IPC network specified in SECTION 16920. This port may be integral to the processor or contained in a separate interface module and shall conform to the following standards:

Type	IEEE 802.3 (TCPIP)
Data Rate	100M bits per second

2.1.3 Interfacing.

2.1.3.1 General. The PLC shall have provisions for interfacing with the remote I/O racks, the IPC Ethernet network, **[and other PLC-controlled devices such as lighting panels, circuit breakers, or adjustable frequency drives]**. This may be accomplished with communication channels integral to the processor or with separate rack-mounted network interface modules.

2.1.3.2 Remote I/O Interface. The PLC system shall be equipped with Remote I/O Interface Modules, as required, to enable the processor to communicate with remote I/O racks located up to 10,000 feet from the processor module. The Remote I/O interface modules shall provide, as a minimum, two (2) physical communication channels to each remote I/O rack. These channels shall back-up each other and upon failure of one channel the processor shall automatically revert to the alternate channel without loss of data. The transmission rate for remote I/O communications shall be a minimum of 5Mbps. The Contractor shall ensure that the manufacturer's recommended maximum cable length and fiber-optic dB budget are not exceeded for this communication rate for arrangements as specified herein **[and as shown on the drawings]**. The quantity of communication modules shall be coordinated with actual remote I/O rack quantities. The interface modules shall be capable of supplying the required number of I/O points and remote drops **[as shown on the drawings and]** as required for proper operation including the expansion capability specified herein. Communication between

the processor and remote I/O shall be serial and be transmitted over fiber-optic cable as recommended by the PLC manufacturer.

2.1.3.3 Fiber Optic Interface Modules. The Contractor shall provide Fiber Optic Interface Modules for each remote I/O rack and other PLC-controlled devices (these may be different models for some manufacturers). The F/O interface modules shall be products developed specifically for use on the supplied PLC network and shall be manufactured or supported by the PLC Manufacturer for use on this system. The modules shall operate on 120 VAC, 60Hz, have full LED diagnostics, and support **[daisy chain][star]** configurations **[as shown on the drawings]**. The F/O modules may operate on a different voltage provided they are powered by dedicated and UL listed power supplies, as recommended by the manufacturer.

2.1.3.4 Other Network Device Interface Modules. The Contractor shall provide **[Lighting Panel][Adjustable Frequency Drive][Designer should include other PLC-controlled devices here]** network interface modules to allow the PLC processor to communicate with these devices **[as shown on the drawings]**. The interface modules shall be products developed specifically for use on the supplied PLC network and shall be manufactured or supported by the PLC Manufacturer for use on this type of system. The modules shall operate on 120 VAC, 60Hz, or shall be provided with separate dedicated and UL Listed power supplies, shall have full LED diagnostics, and may be PLC rack mountable. The Contractor's System Integrator shall be completely responsible for providing a network capable of writing registers to and reading them from **[Lighting Panels][Adjustable Frequency Drives][Designer should include other PLC-controlled devices here]** for the purpose of remote control and monitoring.

2.1.3.5 Interface Cables. The Contractor shall furnish and install all fiber-optic cables, twisted-pair shielded cables, connectors, fiber-optic converters, and hardware to provide a complete system. All materials shall conform to these specifications and the PLC manufacturer's written recommendations.

2.1.4 Rack Assemblies.

2.1.4.1 General. The Contractor shall provide all rack assemblies necessary to contain and construct the PLC system. All I/O cards, racks, power supplies, and other devices, and equipment provided with the PLC system, shall be of the same model or type throughout the system. Each rack shall have plug-in busses and connectors in order to provide data, addressing, power, and ground to the devices installed. The Contractor shall size the rack assemblies to meet all I/O requirements with the expansion requirements as specified herein.

2.1.4.2 Module Retainers. The racks shall have a mechanism to securely retain each module installed and prevent accidental removal or disconnection of any installed device. All I/O cards shall be capable of being removed without interrupting power to the I/O rack.

2.1.4.3 Installation. All racks shall be fully installed in the PLC enclosures, as specified in SECTION 16900 - INSTRUMENTATION AND CONTROL, before delivery. Spacing between racks shall conform to the PLC System Manufacturer's recommended spacing.

2.1.5 Input Modules.

2.1.5.1 General. Input modules shall be provided for both analog and digital signals. Modules shall plug into the rack assemblies for connection to the PLC. All external wiring shall be made by screw terminals that are on a terminal strip or in an intermediate housing to allow disconnection and replacement of a module without removal of any factory wiring. **[The drawings show typical I/O rack wiring intended to demonstrate the general arrangement without being specific to one manufacturer]**. The Contractor shall be responsible for coordinating the I/O card wiring with the PLC manufacturer for proper connection to the field devices. The Contractor shall coordinate all transient suppression re-

quired for inductive loads in accordance with the PLC manufacturer's recommendations. Transient suppression includes, but is not limited to, MOVs, diodes, and capacitors.

2.1.5.2 Analog Input Modules. All analog input modules shall meet or exceed the following:

(1) Inputs per Module	**[8][Specify]**
(2) Ranges	4-20 mA DC, ± 5 VDC, ± 10 VDC
(3) Accuracy	± 0.05% of full scale at 25°C
(4) Update Time	25 ms for all channels (maximum)
(5) Isolation	200 V Continuous
(6) Overload Protection	140 VAC RMS (voltage) 30 mA (current)
(7) Input Impedance	>10M Ohm (voltage) 300 Ohm (current)
(8) Common Mode Rejection Ratio	150 dB (typical)

Each input analog signal shall be converted to a percent of full scale. Each converted value shall be available to the PLC system as an independent, addressable register. All zero and span calibration shall be performed automatically by the module. A front mounted LED shall be illuminated to indicate the module is functioning and communicating properly.

2.1.5.3 Digital Input Modules. Isolated Digital input modules shall be provided that are compatible with [**120 VAC**] signals, [**as indicated on the drawings**]. All digital input modules shall meet or exceed the following:

(1) Nominal Signal Voltage	**[120 VAC]**
(2) Inputs per Module	16
(3) Operating Voltage Range	**[74-138 VAC]**
(4) Input ON Voltage (minimum)	**[74 V]**
(5) Input OFF Voltage (maximum)	**[45 V]**
(6) Input Impedance (minimum)	**[6.9Kohms]**
(7) Maximum Transition Time	**[9 ms]**
(8) Isolation Voltage	1500 VAC

Circuit status lights that illuminate when an input is energized shall be provided for each input. The Contractor shall be responsible for ensuring that the input modules are compatible with the overall performance requirements of Paragraph 16910-2.1.2.4.

2.1.6 Output Modules.

2.1.6.1 General. Output modules shall be provided for digital signals. Modules shall plug into the rack assemblies for connection to the PLC. All external connections shall be made by screw terminals that are on a terminal strip or in an intermediate housing to allow disconnection and replacement of a module without removal of any factory wiring. **[The drawings show typical I/O rack wiring intended to demonstrate the general arrangement without being specific to one manufacturer.]** The Contractor shall be responsible for coordinating the I/O card wiring with the PLC manufacturer for proper connection to the field devices. The Contractor shall coordinate all transient suppression required for inductive loads in accordance with the PLC manufacturer's recommendations. Transient suppression includes, but is not limited to, MOVs, diodes, and capacitors.

2.1.6.2 Digital Output Modules. Isolated Digital output modules shall be provided that are compatible with **[120 VAC]** signals, **[as indicated on the drawings.]** All digital output modules shall be RELAY type modules and meet or exceed the following:

(1) Nominal Signal Voltage	**[120 VAC]**
(2) Outputs per Module	16
(3) Outputs per Common	1
(4) Operating Voltage Range	**[24-250 VAC]**
(5) Current Rating per Output	2 A continuous
(6) Fusing	Each output fused at terminal board
(7) Isolation Voltage	1500 VAC

Circuit status lights that illuminate when an output is energized shall be provided for each output modules. The Contractor shall be responsible for providing external fusing, appropriately sized for each output, for output modules that do not include internal fusing. The Contractor shall be responsible for ensuring that the output modules are compatible with the overall requirements of Paragraph 16910-2.1.2.4. The Contractor shall also ensure that the load for each output module does not exceed the overall current limitations for that module.

2.1.6.3 High Speed Digital Counter Module. Digital high speed counter modules shall be provided that are compatible with both high speed pulse signals and quadrature encoder signals. The high speed counter module shall contain its own microprocessor to allow operation independent of the PLC processor. The unit shall be programmable directly from the PLC network and shall meet or exceed the following:

(1) Counters per module	2 (Minimum)
(2) Maximum Counts	9,999,999
(3) Counter Type	Bi-directional Pulse Quadrature Encoder
(4) Number of Outputs	3

****

Note: High Speed Counter Modules are included for use with hydraulic cylinder position transducers that produce a pulse train (square wave) signal with the movement of the rod. These units also could be used for other applications.

****

2.1.7 DC Power Supplies.

2.1.7.1 General. The PLC system shall be equipped with DC power supplies operating with input power of 120 VAC, 60 Hz and capable of supplying the voltage and power levels required by the equipment served. The Contractor shall use rack-mounted power supplies as available from the PLC System Manufacturer. These power supplies shall only be used to supply power to a PLC rack assembly. Separate DC power supplies, as specified in SECTION 16900 INSTRUMENTATION AND CONTROL, shall be used to provide power for the fiber-optic converters and field devices including analog inputs and discrete I/O points. Also, I/O rack power supply signal conditioners shall be provided as specified in SECTION 16900 – INSTRUMENTATION AND CONTROL.

2.1.7.2 Surge Protection. Each power supply shall suppress all surges up to and including 1000 V peak for up to 500 microseconds, without causing any interruption of the program in progress.

2.1.7.3 Noise Suppression. Each power supply shall comply with NEMA Standard ICS 3, Section ICS 3-304.42, Electrical Noise Tolerance.

2.1.7.4 Power Loss Ride Through. Each power supply shall be capable of enduring a minimum duration of 33 ms (one-half cycle) of AC power loss with no effect on the output voltage or power levels.

2.1.8 EMI/RFI Resistance. Each component of the PLC shall be capable of resisting interference in conformance with NEMA Standard ICS 3.

2.1.9 Environmental Conditions. All PLC components shall be rated to operate over a temperature range of [**0 to 60 degrees C**][**32 to 140 degrees F**] and a humidity range of 0% to 95% non-condensing.

2.1.10 Data Line Protectors. All copper communication cables that exit the enclosure from where they are generated shall be provided with data line surge protectors. Data line protectors shall be of the gas-tube type and be as provided by or as supported by the PLC manufacturer for use on this system.

2.1.11 Miscellaneous Hardware. The PLC system shall be furnished with all interconnecting cables, connectors, hardware, and other required appurtenances to provide a complete, operational, and functionally sound system.

2.2 SPARE PARTS

****

Note: Spare part quantities designated here are for guidance only. The designer should consider the project, the location, the projected type and amount of usage and determine appropriate quantities for the spare parts.

****

2.2.1 General. Spare parts shall be provided by the Contractor to the Government as specified herein. Unless specifically stated otherwise, all spare parts shall be provided in their original shipping containers. All containers shall be resealed after visual inspection by the Contractor prior to being turned over to the Government.

2.2.2 PLC Processor Module. One PLC Processor Module shall be provided for each unit installed at the project and shall be identical to that unit.

2.2.3 Interface Modules. Two of each type of module required for all interface functions shall be provided. This shall include, but not be limited to, any necessary Network Interface Modules, Remote I/O Modules, Fiber Optic Interface Modules, [**Lighting Panel Interface Modules**][**Adjustable Frequency Drive Interface Modules**], and Ethernet Network Interface Modules.

2.2.4 Rack Assemblies. Two spare rack assemblies shall be provided for each type and/or size of rack assembly installed in the PLC system.

2.2.5 I/O Modules. Three (3) spare modules shall be provided for each type of module supplied with the PLC system. This includes, but is not limited to:

(1) Digital input modules.

(2) Digital output modules.

(3) Analog input modules.

2.2.6 Power-Supplies. Three (3) backup power supplies shall be provided to the Government in their original packaging for each type and size of power supply furnished with the PLC system.

2.3 SPARE I/O.

General. The PLC system shall be provided with a minimum of 20 percent spare I/O capacity of each type at each I/O rack location wired to terminal blocks. An additional 20 percent space shall be available for future expansion by providing either empty card slots, or space for additional I/O racks within the enclosures. Space shall also be allowed for the number of terminal strips and interposing relays to increase capacity by 20 percent. Power supplies and memory shall be of sufficient size to serve this expansion.

2.4 SOFTWARE.

2.4.1 PLC Programming Software. The Contractor shall provide all software necessary to program the PLC using the IPC network specified in SECTION 16920 – INDUSTRIAL PERSONAL COMPUTERS AND SOFTWARE. This software shall be of the same manufacture as the PLC system or as recommended by the PLC manufacturer. All software shall be windows-based and compatible with the IPCs specified in SECTION 16920. This software shall include any utility programs or developmental packages offered with the programming software. All programming software shall meet the minimum requirements as specified below:

(1) Software shall perform the rack addressing for local and remote racks.

(2) Software shall provide a graphical means of programming the functions specified in Paragraph 16910-2.1.2.4 above using IEC standard PLC programming as defined in IEC 1131-3. Software shall allow "on-line" or "off-line" programming, provide a means of "forcing" inputs and outputs, and saving and loading control programs.

(3) Software shall contain searching and editing functions and allow the use of labels and rung descriptions.

(4) Software shall have a means to "open circuit" an instruction (rung) or "short circuit" a permissive function.

(5) For troubleshooting purposes, the software shall provide a means of monitoring the program while the processor is in operation. The software shall display the status of the inputs and outputs as the user scrolls through the logic. The software shall also be capable of displaying the contents of any internal registers as well as the results of function blocks.

(6) Programming shall include standard 'drag and drop' functions to allow I/O addresses and labels to be lifted from database tables and entered into program ladders. All labels and descriptions shall automatically be programmed into the ladder this way.

2.4.2 Graphical User Interface Software. See SECTION 16920 - INDUSTRIAL PERSONAL COMPUTERS AND SOFTWARE.

PART 3 - EXECUTION

3.1 INSTALLATION.

3.1.1 General. All equipment furnished under this section shall be installed [**as shown on the drawings,**] as recommended by the manufacturer, and in accordance with the National Electric Code. When these guidelines appear to be silent or in conflict the Contracting Officer shall make the final decision. The PLC manufacturer shall, in writing, ascertain that the contractor's installation is in accordance with their written installation guidelines.

3.1.2 I/O Rack Addressing. The Contractor's System Integrator shall be responsible for all rack addressing of the PLC system. The Contractor's System Integrator shall submit the proposed rack addressing for Government approval no later than 30 days past the acceptance of the Contractor's PLC System manufacturer. The rack addressing shall provide each I/O module with the necessary number of registers. Memory map table shall be [**as shown on the drawings or**] as required by the PLC manufacturer.

3.1.3 Ladder Logic Programming.

****

Note: The best way to convey the intent of the ladder logic programming is to provide the contractor with relay type ladder programming with function blocks showing the general logic and interlocks desired for operation of the locks. The actual PLC programming implemented by the Contractor's System Integrator will likely appear quite different from this, but it is important to give the contractor some general guidance of how the programming should control the lock. In lieu of relay logic the designer could provide operational requirements and procedures in sentence form, but this is usually not as effective as guidance provided through ladder programming.

****

[**The programming as shown on the drawings is intended to give the Contractor a general idea of the functions of the lock equipment. It is in no way intended to be specific in nature and does not reflect the programming characteristics of a particular PLC type.**] The Contractor's System Integrator shall be completely responsible for providing all software and implementing all programming as required to provide a completely functional and properly operating PLC system. The Contractor's System Integrator shall [**use the drawings as a guideline to**] develop a complete, correct, and properly operating PLC ladder program.

3.2 TRAINING.

3.2.1 Formal Programming Training. The Contractor's System Integrator and/or the PLC System Manufacturer shall provide, at the Government's discretion, a programming training class for a maximum of [**six (6)**] individuals of the

Government's choosing. The training shall take place no later than 30 days past the approval of PLC submittal. This training shall consist of a minimum of 80 hours of instruction given by a staff member(s) of the PLC manufacturer. The training instructors shall be familiar with all the software used in the PLC system and have previously developed control applications with that hardware and software and provided training sessions similar to that required herein. This training may be the PLC Manufacturer's standard commercially available classroom training. The subject matter of the training sessions shall include, but not be limited to:

(1) Rack Addressing and commissioning of a PLC network.

(2) Basic and advanced IEC 1131 PLC logic programming.

(3) Integration of all PLC-controlled device commands and functions into the ladder logic.

(4) Scaling analog values for position indication in the GUI.

(5) Network applications.

(6) Development and programming of a GUI control system.

The sessions shall provide "hands-on" training with the software, hardware, and other equipment used in the PLC system in which a specific example is physically developed during the training session. The location of the training shall be determined by the Contractor.

3.2.2 Informal Programming Training. The Contractor's System Integrator shall provide a dedicated programming training class for a maximum of **[six (6)]** individuals of the Government's choosing. The training shall take place no later than 30 days past the formal training specified in paragraph 16910-3.2.1. This training shall consist of a minimum of 40 hours of instruction given by a staff member(s) of the Contractor's System Integrator. The training instructors shall be familiar with all the software used in the PLC system and have previously developed control applications with that hardware and software and provided training sessions similar to that required herein. In contrast to the formal training specified in 16910-3.2.1, this training shall be dedicated to the Government and the subject matter shall be specifically tailored to the application as defined by these plans and specifications. The execution of this training may vary as the Contractor's System Integrator chooses, but shall generally follow this outline and shall, as a minimum, cover all topics delineated below:

(1) A mock PLC system, including the processor and rack, a minimum of 2 remote I/O racks with remote interface cards, digital and analog I/O cards, and power supplies shall be constructed in a shop type facility away from the project site. Government personnel, under the instruction of the trainers, shall be allowed to actually assemble the equipment.

(2) A mock IPC network shall be assembled to facilitate programming and operation of the training session PLC system.

(3) Installation of the PLC programming software and communication with the processor.

(4) Remote I/O rack Addressing.

(5) The training session shall have available pushbuttons, toggle switches, pilot lights, and analog signal generators to simulate I/O. These shall be wired to the I/O cards as part of the training.

(6) Basic and advanced IEC 1131 PLC logic programming shall be used to manipulate the mock I/O data.

(7) Analog signal values shall be scaled and conditioned similar to applications as required by the project.

(8) A GUI interface shall be developed for control and monitoring of the mock PLC system.

The training shall take place at the System Integrator's shop or other location as approved by the Contracting Officer. The Contractor's System Integrator may pre-assemble the equipment and pre-develop the training software applications provided that these are accomplished again as part of the training. This portion of the training may be combined with that as specified in SECTION 16920 - INDUSTRIAL PERSONAL COMPUTERS AND SOFTWARE, or with testing requirements from this and other portions of the specification provided that the requirements of all are met.

3.2.3 Maintenance Training. The Contractor's System Integrator and/or the PLC System Manufacturer shall provide an eight-hour training session at the job site for maintenance personnel. Training topics shall include, but are not limited to, preventive and corrective maintenance procedures, troubleshooting and testing techniques. This training shall be coordinated with the training specified in SECTION 16920 for the IPC network. In addition, during the final adjustments and the final acceptance tests, the Contractor shall instruct and demonstrate to designated Government personnel all of the operation, preventive maintenance, adjustment, and test procedures. All lock maintenance personnel shall also be permitted to observe the various maintenance procedures performed on the PLC equipment by the Contractor during the guarantee and service periods.

3.2.4 Operation and Maintenance Instructions. Five complete bound sets of operating and maintenance instructions on the PLC system shall be provided. The manuals shall include complete and as-built data on every component in the PLC system, circuit diagrams, parts lists, PLC programming, I/O listing with documentation, and adjustment and trouble-shooting procedures.

3.3 TESTING.

3.3.1 General. The PLC system shall be subject to factory and site acceptance testing. The Contractor's System Integrator shall prepare a system test procedure to be approved by the Contracting Officer which shall demonstrate conformance of the PLC system to the specifications and proper performance of all the required control functions, including interfacing with the IPC network. The test procedure shall include an outline in a checklist format for ease of compliance verification. The test shall be performed by the Contractor's System Integrator and witnessed by the Contracting Officer. The Contractor shall notify the Contracting Officer in writing at least 14 days prior to the proposed date for commencing the tests. The Contracting Officer, depending on weather conditions or river conditions, may postpone any or all parts of the site acceptance test until such time that a full acceptance test can be performed. The Contractor shall be responsible for any damage to equipment during testing.

3.3.2 Factory Acceptance Testing. In conjunction with the IPC factory test the PLC system shall be tested. The Contractor's system integrator shall be required to assemble a mini test version of the proposed PLC system including processor rack, a minimum of two remote racks, power supplies, fiber optic modules, Ethernet network interface modules, at least 2 IPC workstations, and mock I/O devices such as switches, pilot lights, and analog current generators. All types of I/O and ladder programming shall be developed at the factory testing. This testing may occur at the same time as the training specified herein and in Section 16920 so long as requirements for both are met.

3.3.3 Site Acceptance Testing. After installation of the systems and checkout by the Contractor's System Integrator personnel, a site acceptance test shall be performed. The Contractor's System Integrator shall be responsible for software programming necessary for acceptance testing. A listing of all testing programs shall be submitted for Government approval. The test shall demonstrate the correct connection of all inputs and outputs. Any devices connected to the PLC system shall be shown to be in proper working order. To facilitate testing of the PLC/IPC network, all acceptance testing shall be done through the GUI software. Control screens shall be used to demonstrate the following:

(1) Correct operation and instrumentation of all lock and dam equipment including, but not limited to, miter gates, valves, dam gates, traffic lights, lock and dam lighting, bubbler systems, and air compressors. All equipment shall be operated only after coordination with, and approval from, the Lockmaster.

(2) Correct display of all values on the operating screens including, but not limited to, water levels, miter gate position, valve position, dam gate position, and status of lock lighting, traffic lights, navigation lights, dam lighting, and outdraft lighting.

-- End of Section --

****

SECTION 16920
INDUSTRIAL PERSONAL COMPUTERS AND NETWORKS

****

Note: This guide specification covers the requirements for procurement and installation of electrical and electronic devices provided with the Industrial Personal Computers and associated networking equipment. This guide specification is intended to cover both new lock construction as well as rehabilitation work. With some editing this guide specification can be used for other civil works projects as well. When using this guide specification the designer will be required to include portions of CEGS 16120 – INSULATED WIRE AND CABLE, CEGS 16768 – FIBER OPTIC DATA TRANSMISSION SYSTEMS, CEGS 16792 – WIRE LINE DATA TRANSMISSION SYSTEM, CEGS 16794 – COAXIAL CABLE DATA TRANSMISSION MEDIA, and CEGS 16910 – PROGRAMMABLE LOGIC CONTROLLER. This guide specification is to be used in the preparation of project specifications in accordance with ER 1110-345-700 for military construction and in accordance with ER 1110-2-1201 for civil works construction.

****

PART 1 - GENERAL

1.1 REFERENCES.

****

Note: Issue date of references included in project specifications need not be more current than provided by the latest change (Notice) to this guide specification.

****

The publications listed below form a part of this specification to the extent indicated by the references thereto. The publications are referred to in the text by basic designation only.

American National Standards Institute (ANSI).

C37.90 (1989; R 1994)	Standard for Relays and Relay Systems Associated with Electric Power Apparatus

Institute of Electrical and Electronic Engineers (IEEE).

802.3 (1996)	Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements - Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications
802.3U SUPP (1995)	Supplement to Local and Metropolitan Area Networks Media Access Control (MAC) Parameters, Physical Layer, Medium Attachment Units, and Repeater for 100 Mb/s Operation, Type 100BASE-T (Clauses 21 - 30)

National Electrical Manufacturer's Association (NEMA).

ICS 1 (1993)	Industrial Control and Systems General Requirements

1.2 SYSTEM DESCRIPTION

This specification section addresses the procurement, programming, and installation of the industrial personal computers (IPCs) and associated hardware and software. The Contractor shall furnish all plant, labor, equipment, material, and perform all operations to install, test, and demonstrate a working IPC system as functionally defined herein [**and as shown on the drawings**]. The IPCs serve as the interface between the operators and the programmable logic controller (PLC) system. The scope of this project includes connecting different vendor's equipment to a common communications network. It shall be the responsibility of the Contractor to provide systems integration services and to furnish and install all labor, materials, hardware, software, and testing, as required, to provide fully functional networks. This specification is divided into two major sections: hardware and software. Unless otherwise noted, all electrical equipment installed under this specification shall be installed in accordance with SECTION [**CEGS 16120 – INSULATED WIRE AND CABLE, CEGS 16768 – FIBER OPTIC DATA TRANSMISSION SYSTEMS, CEGS 16792 – WIRE LINE DATA TRANSMISSION SYSTEM, and CEGS 16794 – COAXIAL CABLE DATA TRANSMISSION MEDIA**] - and SECTION 16910 – PROGRAMMABLE LOGIC CONTROLLER.

1.2.1 Hardware. The hardware section covers the furnishing and installation of [**quantity**] IPCs, [**quantity**] notebook computers, networking components and support equipment for monitoring, control, and operation of project machinery and equipment. The major hardware shall include, but is not limited to, the following principal items:

(1) IPC consisting of chassis, central processing unit, memory, storage devices, video display adapter, and network interface card, as indicated [**on the drawings and**] in this specification

(2) High resolution LCD flat screen color video display monitor

(3) Keyboard and other input devices, as required, by the software

(4) Mouse unit and pad

(5) Color ink-jet printer

(6) Black & white laser printer

(7) High-speed PCMCIA modem

(8) Dial-up router

(9) Network hub

(10) Network transceiver

(11) Local Area Network (LAN) to provide communication between the network hub, IPCs, PLCs, modems, printers, network interface cards, and transceivers

(12) Notebook portable computer (IPC Portable Station)

(13) All cabling, connectors and support equipment required to ensure a complete and functional system

In general, if a component meeting this section's specifications is available from the manufacturer who is supplying a more significant component, then that manufacturer's product shall be used. Components of the IPC, including power supply, central processing unit, video display monitor, video display adapter, memory cards, network interface card, I/O controller cards, keyboard, hard drive, floppy drive, modem, or printer may be of different manufacturers, but those components that serve the same function shall be of the same manufacturer. There shall be no differences in manufacturers between the components comprising each IPC. The Contractor's System Integrator shall be responsible for coordinating the selection and purchase of equipment to ensure that all IPC components and peripherals are compatible and that they have been tested and are suitable, as recommended by the IPC manufacturer, for use with an industrial grade personal computer.

1.2.2 Software. The software section covers the furnishing of standard software, fully installed and configured in the computer systems. It is the intent of this specification section to have the Contractor furnish standard operating system software, control software for operation of equipment, network software, programming software for the PLC system, and all software necessary to meet the functional requirements specified herein. Software specified in this section is described in broad, functional categories. The Contractor shall furnish a complete software package including the functional requirements specified in this section along with whatever additional software is required for proper operation of the system. The Contractor shall program the control software for operation of the facility. It is the responsibility of the Contractor and its System Integrator to ensure that the control software is properly configured and tested. All software developed under this contract shall become the property of the Government.

1.3 SUBMITTALS

****

Note: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item is required.

Indicate submittal classification in the blank space using "GA" when the submittal requires Government approval or "FIO" when the submittal is for information only. It is a good idea to require that all of the IPC and Network equipment shop drawings be submitted together for approval. This allows the designer to review the whole system for compatibility and integration. It is also a good idea to require that portions of the PLC submittal (Section 16910) be submitted with the IPC shop drawings to insure overall integration of the computerized system.

■■■

Government Approval is required for submittals with a "GA" designation; submittals having an "FIO" designation are for information only. The following shall be submitted in accordance with Section 1330 SUBMITTAL PROCEDURES:

[SD-16920-01 IPC System Components
IPC Chassis (GA)
CPU (GA)
Passive Backplane (GA)
Storage Devices (GA)
Video Display (GA)
Video Display Adapter (GA)
Sound Card (GA)
Speakers (GA)
Printers (GA)

SD-16920-02 Network Equipment
Router (GA)
Hub (GA)
Network Interface Cards (GA)
Transceivers (GA)
Cable (GA)

SD-16920-03 Software
Operating System (GA)
PLC Programming (GA)
GUI/HMI (GA)

SD-16920-04 System Integrator
Qualifications (GA)
Experience (GA)
References (GA)

SD-16920-05 Programming
Operating System Parameters (GA)
Tag Database (GA)
GUI/HMI Operator Screens (GA)

SD-16920-06 Schedules.
Industrial Personal Computer System Training (GA)
Industrial Personal Computer System Testing (GA)

SD-16920-07 Manuals and Literature.
Manuals and Literature for all IPC and Network equipment (FIO)]

1.4 PROJECT/SITE CONDITIONS

1.4.1 Environmental Requirements

The environment into which the electrical equipment will be installed is an outdoor facility subject to 100 percent humidity and temperature variations between [ ] degrees [**C**][**F**] and [ ] degrees [**C**][**F**]. The Contractor shall ensure that during installation all equipment is properly handled and stored so that it is not damaged by adverse environmental conditions. The Contractor shall also ensure that the final installation of equipment meets the environmental requirements of the manufacturer.

1.4.2 Existing Conditions

****

Note: The designer shall use this section to delineate any special existing conditions that affect the work as specified herein. This is a particularly important section for contracts that include rehabilitation of lock control systems. In some cases existing machinery or electrical distributions systems will be reused by the contractor. These items should be explained in this part of the specification using sufficient detail to fully convey existing conditions and requirements necessary to bid and complete the contract work.

****

1.5 DELIVERY, STORAGE, AND HANDLING

Equipment specified in this section, comprised of electrical and electronic components, hardware and software, shall be scheduled for shipment to arrive on the job site no more than [ ] days

****

Note: The amount of time electronic equipment can be stored at the job site is specified to preclude prolonged storage and possible obsolescence of some equipment. Large construction contracts can have durations of several years and some electronic equipment as well as software can go through several revised releases during that time. The designer should be careful to allow enough lead-time not to effect the construction schedule but not excessive time. Sixty days is a good starting point. The designer should refine this for each project.

****

prior to its scheduled installation date. Upon delivery at the work site, the Contractor shall store all Industrial Personal Computer equipment in designated areas [**as shown on the drawings**]. The conditions under which any equipment or materials are to be stored shall be in accordance with the manufacturer's recommendations and with the best standard practices to ensure that all equipment and materials will be in pristine condition at the time of installation. The Contractor shall familiarize itself with regard to the location of all other equipment, materials, and conditions that may affect the electrical work sequence so as to minimize any interference with other installations or to subject any items to detrimental conditions. The exact storage location of all electrical and electronic items shall be subject to the approval of the Contracting Officer.

1.6 STANDARD PRODUCTS

Unless otherwise approved by the Contracting Officer, the materials and equipment to be furnished under this specification shall be standard products of manufacturers regularly engaged in the production of such equipment and shall be the manufacturer's latest standard design.

****

Note: Technology changes rapidly in the PC/network area. The designer shall make manufacturer surveys to ensure that all equipment is of the latest technology incorporating the relevant latest features.

****

Items of equipment shall be of the same product line as equipment that has been in satisfactory use at least two years prior to bid opening. Like equipment for similar service shall be of the same manufacturer, and when of the same size and rating, shall be interchangeable. Equipment shall be supported by a service organization that is, in the opinion of the Contracting Officer, reasonably convenient to the site.

1.7 GENERAL ARRANGEMENTS

The general arrangements and approximate locations of the Industrial Personal Computers and other Network devices, conduit and wiring connections shall be [**as indicated on the drawings.**] Subject to the approval of the Contracting Officer, the Contractor may modify the layout [**indicated on the drawings or**] specified herein, to more readily conform to the space available and to the equipment proposed for use. Should the approved equipment furnished be of a different size than indicated, at his own expense the Contractor shall make the necessary adjustments to the branch circuit wiring (8 AWG and smaller), disconnecting devices, branch-circuit protection, component wiring, component installation, IPC programming, IPC component quantities, and space requirements to accommodate the equipment actually installed.

1.8 QUALIFICATIONS

A Systems Integrator shall be used by the Contractor to furnish and install the IPC network system. This firm will be referred to as the "Contractor's System Integrator"; the same firm as specified in Sections 16900 and 16910. The Contractor's System Integrator shall be familiar with all hardware and software supplied under this specification section. The Contractor's System Integrator shall show evidence that it has previously integrated hardware and software of the same product line to that intended to be used for this job. All work shall be performed in a skillful and workmanlike manner in accordance with the best modern shop practice for the manufacture of finished products of a nature similar to those covered by these specifications, and shall be performed by mechanics and technicians especially skilled for each kind of work and under competent supervision and direction. All materials and equipment shall be installed in accordance with recommendations of the manufacturer as approved by the Contracting Officer.

1.9 SEQUENCING AND SCHEDULING

****

Note: This paragraph includes any special sequencing or scheduling of work unique to the project. Rehabilitation of existing lock control systems often will require special sequences and schedules and these should be spelled out in sufficient detail to convey the importance to the Contractor. Lock closure times and other limitations such as requirements for back-up generator sets should be included here as technical requirements necessary for a Contractor to bid and construct the project.

****

1.10 WARRANTY

All equipment and material installed under this section shall be warranted to be free of defects in workmanship and material for a minimum of one year after acceptance by the Contracting Officer. The Contractor shall make written transfer of all manufacturer's warranties to the Government upon acceptance of the work by the Contracting Officer.

1.11 CODE COMPLIANCE

All work, specified herein [**or shown on the drawings**], shall conform to the applicable rules of NFPA Code No. 70 National Electric Code, ANSI C2 National Electrical Safety Code, and other sections of this specification.

PART 2 - PRODUCTS

2.1 Hardware.

****

Note: If the designer does not intend to use a section for general electrical requirements including wire and cable, appropriate portions of CEGS 16120 WIRE AND CABLE must be incorporated here.

****

2.1.1 General. The specifications that follow indicate the extent and general arrangement of the systems. If any departures from the drawings or specifications are deemed necessary by the Contractor's System Integrator or manufacturer, details of such departures and the reasons shall be submitted to the Contracting Officer for review. No such departures shall be made without prior written approval. The General System Requirements shall apply to all equipment furnished under this section. All hardware interfaced to or directly controlled by an IPC running a Microsoft operating system must be listed in Microsoft's hardware compatibility list. This specification describes the minimum requirements for hardware and software. Where the Contractor's actual system manufacturer's standard configuration includes additional items of equipment or software features not specifically described herein, they shall be furnished as a part of the system.

2.1.1.1 Factory Assembly. Equipment shall be shipped completely factory assembled, except where the physical size, arrangement, or configuration of the equipment, or shipping and handling limitations, make the shipment of completely assembled units impracticable.

2.1.1.2 Expandability. The system shall, as a minimum, be expandable to provide the following capabilities:

(1) An archival device (removable magnetic tape or optical disk drive) on the LAN

(2) Additional hard disk capacity for each IPC

(3) Three slots shall be available for adding interface cards. Main memory shall be expandable up to a minimum of 512 megabytes (MB)

(4) Replacement of graphic displays with higher resolution units

(5) Addition of IPCs or PCs to the LAN.

2.1.1.3 Power Supply. Unless otherwise specified, power supply to all equipment shall be 120 volts, 60 Hz, single phase. The Contractor shall be responsible for distribution of power between enclosures, consoles, peripherals, and other components of the system from receptacles and junction boxes [**as indicated on the drawings**]. Power distribution hardware shall include cables and branch circuit overcurrent protection installed in accordance with NFPA-70 The National Electric Code. All power supplies to obtain voltages required by the IPC manufacturer's equipment other than those provided above shall be an integral part of the equipment furnished. Internal power supplies shall be regulated, current-limiting, and self-protected. All equipment furnished hereunder shall meet all surge withstand capability tests as defined in ANSI C37.90 without damage to the equipment. All equipment furnished shall be capable of tolerating and operating through a power interruption of 8 milliseconds or less without interruption of normal operation. All equipment supplied under these specifications shall be designed to prevent the generation of surges into the power source during normal operation.

2.1.1.4 Spare Parts. All spare parts shall be of the same make and model as provided for normal use. The following spare parts shall be provided in quantity as specified below:

(1) One spare passive backplane

(2) One spare controller board

(3) One spare video adapter card

(4) One spare network interface card of each type

(5) One spare hard drive

(6) Five spare toner cartridges for the black and white laser printer

(7) Fifteen spare black, five cyan, five yellow, and five magenta ink cartridges for the color ink-jet printer

(8) Four boxes (5000 sheets each) of 20 lb, 8.5 x 11, white laser printer paper

(9) Four boxes (quantity 40) of 3.5 inch high density computer disks, IBM formatted to 1.44 megabytes

(10) One spare mouse

(11) One spare keyboard

(12) Two spare fiber optic transceivers.

All spare parts shall be furnished to the Contracting Officer before final acceptance of the system. Spare parts shall be packaged to exclude dust and moisture and shall be suitable for storage. Spare parts and supplies shall not be consumed during installation, debugging, startup or training operations and shall be available in the quantities specified at the time of final acceptance. The Contractor's System Integrator shall provide replacement for all supplies partially or totally consumed before final acceptance of the systems.

Cables. The system shall be furnished with all power cords and interconnecting data cables required for the proper operation of the system. All cord-connected equipment shall be furnished with 3-wire grounded cord and plug assemblies at least eight feet in length. Cables for transmission of digital signals and data between components of the system shall be multi-conductor, round, and shielded with multi-pin Electronic Industries Association (EIA) standard connectors.

****
Note: The designer should add EIA to SECTION 01090 – SOURCES FOR REFERENCE PUBLICATIONS.
****

Connectors shall have metal hoods, gold plated contacts and screw or clip-type securing devices. Flat ribbon cables with crimp-on plastic body connectors will not be permitted except between equipment devices in the same enclosure (consoles shall not be considered an enclosure, for this definition). Cable lengths shall be as required for the equipment layout [**as indicated on the drawings**]. Keyboard cable shall be flexible and self-coiling, and at least six feet in length. Keyboards for consoles in control stations shall be mounted on pull-out drawers integral to the consoles. Keyboard cable shall be routed within the consoles and shall be retractable with the drawers.

2.1.2 Computer System Hardware.

2.1.2.1 IPC Computer Chassis. The computer chassis shall be mounted in the control consoles [**as shown on the drawings**]. The contractor is responsible for providing adequate space for cables and ventilation. The chassis shall be from the same manufacturer as the central processing unit controller board, and shall have the following features:

(1) The chassis shall be of a rugged design made of heavy gauge steel for industrial or commercial environments and provide protection against vibration and airborne contaminants.

(2) A minimum 250 watt, 120 VAC power supply shall be provided. A cooling fan shall be provided in the power supply module. A second, independent, front-mounted, filtered intake fan shall be provided in the chassis for additional cooling and for pressurizing the inside of the chassis.

(3) The chassis shall be sized for a 15-slot passive backplane. Adapter card restraints for the backplane shall be provided with the chassis top cover.

(4) Front panel controls and indicators shall include a disk activity LED, a power on LED, power on/off switch, system reset, and speaker volume adjust. Except for the LEDs, the controls shall be located behind a key lockable access door. Each computer access door shall be keyed alike and a key shall be provided with each chassis.

(5) Space for one front-mounted 3.5 inch floppy drive, one front-mounted CD-ROM drive, and two 3.5 inch fixed drives shall be provided. All devices shall be vibration mounted. Devices shall be front accessible behind a key lockable disk access door.

(6) Rear panel connectors shall include, as a minimum, an AT keyboard connector, AC input power connection, AC output power connection, and two DB9 serial connectors.

2.1.2.2 Central Processing Unit (CPU) Controller. The central processing unit controller shall consist of a single board controller with microprocessor installed in the CPU slot of the passive backplane and shall be provided with functions as listed below. <u>A single motherboard type design will not be acceptable</u>.

****
Note: Because technology advances very quickly in this field, the designer will be required to research the market and update the following specifications for each project.
****

Processor

(1) Intel [**Pentium II 450**] MHz

(2) 512K Level 2 Cache

(3) Fan-cooled heat sink

(4) [**100**] MHz bus.

Backplane

(1) 15 slots total

(2) [**Six**] ISA slots, at least [**four**] full length

(3) [**Six**] PCI slots, at least [**two**] primary.

CPU Controller Card

(1) [**100**] MHz CPU bus frequency

(2) Chip set: [**Intel 440BX AGP**]

(3) ISA-AT bus

(4) PCI bus [**33**]MHz

(5) AGP bus [**100**]MHz local memory interface

(6) Memory: [**128**]MB SDRAM ([**100 MHz, 8ns**])

(7) EIDE fixed disk controller on PCI local bus, supporting up to four drives

(8) Dual floppy drive controller, supporting 2.88MB, 1.44MB, 1.2MB, and 720K floppy drives

(9) SCSI-3 controller, PCI Ultra2 wide

(10) Real-time clock with battery backup protection

(11) Dual serial ports, 16550 compatible with 10-pin IDC and rear panel DB9 connectors

(12) Single parallel port controller with bi-directional capability and rear panel DB25 connector

(13) Universal Serial Bus (USB) support

(14) Speaker controller

(15) PS/2 keyboard controller

(16) PS/2 mouse controller, Microsoft compatible.

The [**Pentium II**] processor, controller card, and backplane shall meet or exceed the environmental operating requirements specified herein.

2.1.2.3 Storage Devices. Each IPC shall include one hard disk drive, one 3.5 inch floppy disk drive, and one CD-ROM drive. The hard disk drive will be used to store all system software, database information and all run-time data including display screen formats, report formats and the most recent process data. The floppy disk drive will be used to store historical data records and for occasional backup of data on the hard disk. The floppy disk will also be used to load small software modifications onto the system. The CD-ROM drive will be used to load system or application software which is more conveniently installed from CD-ROM discs.

2.1.2.3.1 Hard Disk Drive. One EIDE or SCSI hard disk drive shall be supplied with each IPC. The formatted drive capacity shall be a minimum of [**2.1**] gigabytes. The drive shall have an average seek time of [**10**] milliseconds or less, and shall park the heads on an unused area of the disk when the unit is turned off or loses power. When possible the drive shall be configured with a single logical partition. Otherwise the drive shall be configured with the maximum size boot partition allowable for the particular drive, with the remaining disk space partitioned to the maximum size allowed. All partitions shall be configured with the NTFS file format. The drive shall interface with either the EIDE or SCSI controller.

2.1.2.3.2 Floppy Disk Drive. One floppy disk drive shall be supplied with each IPC. The drive capacity shall be 1.44 megabytes, using industry standard formats and 3.5 inch rigid plastic encased media. The drive shall interface with the floppy disk controller.

2.1.2.3.3 CD-ROM Drive. One [**32x**] speed CD-ROM drive shall be supplied with each IPC. The drive shall be internally mountable in a 5.25 inch drive slot in the IPC chassis. The drive shall have a transfer rate up to [**2400**] kilobytes (KB) per second. The drive shall interface with either the EIDE fixed disk controller or SCSI-3 controller.

2.1.2.4 Video Display System. A video display monitor and video adapter shall be supplied with each IPC. The video adapter shall be installed in the passive backplane within the IPC chassis and a video display monitor mounted on top of the control console.

2.1.2.4.1 Video Adapter. The video adapter shall provide a minimum high resolution of [**1280 x 1024**] pixels, non-interlaced, with 65,536 colors. The video adapter shall utilize the [**PCI**] local bus and be installed in one of the slots in the passive backplane.

2.1.2.4.2 Video Display Monitors. The video display monitor shall be of the bench top type. The monitor shall be a [ ] mm ([ ]-inch) flat screen LCD display with the following features:

Resolution	[**1280 x 1024**] (H x V)
Colors	Unlimited
Power Supply	120VAC, 60 Hz
Horizontal Viewing Angle	[**160**] degrees
Vertical Viewing Angle	[**160**] degrees
Input Signal	Video: Analog RGB
Signal Cable	Compatible with video adapter card
Operating Temperature	5 – 30 degrees C

In addition, the monitors shall have controls for brightness, contrast, horizontal position, and vertical position. Monitors shall be provided with cables of sufficient length to connect to the IPC mounted inside the control console.

2.1.2.5 Sound Card. A sound card shall be provided for each IPC. The sound card shall have **[16-bit]** stereo sound with selectable sampling and playback rates from 5 kHz to 44.1 kHz. Recording sources shall include microphone, stereo line-in, and CD-audio. The sound card shall include an output power amplifier providing 4 watts minimum per channel at 4 ohms.

2.1.2.6 Speakers. Stereo speakers shall be provided with each IPC. Speakers shall provide 3 watts minimum power per channel with a frequency range better than or equal to 95 Hz - 16 kHz.

2.1.2.7 Keyboard. A standard IBM AT 104-key keyboard shall be provided which can be installed in the keyboard slide assembly mounted in the control console. Each keyboard shall include a standard typewriter arrangement of alphanumeric symbols, vertical and horizontal tab keys, a standard numeric pad, separate cursor direction controls with a home key, and function keys. The keyboard shall be connected to the rear of the IPC chassis with the cable routed inside the console. A protective keyboard overlay film which inhibits dust and liquid contaminants shall be provided with each keyboard.

2.1.2.8 Mouse Unit. A standard two-button Microsoft compatible serial mouse of the rolling ball type shall be provided with each IPC. A mouse pad shall also be provided with each mouse.

2.1.3 Printers. The system shall include one color ink-jet printer and one black and white laser printer. Printers shall be as specified herein **[and installed as shown on the drawings]**.

2.1.3.1 Color Ink-Jet Printer. The system shall include a color ink-jet printer having a minimum print speed of eight letter-size text pages per minute, two letter-size text and graphics pages per minute and one letter-size graphics page per minute. Memory shall be a minimum of 6 MB. Resolution shall be 300 by 300 dpi for color and 600 by 600 dpi for black and white. The printer shall be compatible with the **[Centronics] [USB]** interface included with the single board CPU and shall include a direct interface to the Ethernet LAN. **[The printer shall be located as shown on the drawings]**.

2.1.3.2 Black & White Laser Printer. The system shall include a laser printer with a minimum print speed of 24 letter-size text pages per minute, a minimum of 12 MB of memory, and resolution of 600 by 600 dpi. The printer shall handle standard 8.5x11 (500 sheets) and 11x17 (100 sheets) printing paper. The printer shall be compatible with the **[Centronics] [USB]** interface included with the single board CPU and shall include a direct interface to the Ethernet LAN. The printer shall be located in the control console on pull-out shelves and be provided with interface and power cables long enough to allow for full movement of the shelves.

2.1.4 Local Area Network (LAN). Communication between the IPCs, the PLC, the printers, and the modems shall be provided by a client-server based LAN. One IPC **[located in the central control station]** shall be configured to operate as the server. The remaining IPCs shall be configured as networked clients. The network shall be 100 Mbps Fast Ethernet and comply with IEEE 802.3u. The data transmission rate on the network shall be 100 Mbps for IPCs and notebook computers and 10 Mbps for all other devices. The transmission media shall be 100BASE-TX unshielded twisted-pair (UTP) Category 5 cable and 100BASE-FX multimode fiber optic cable. Twisted-pair cable shall only be used for short distances between the IPCs, dial-up router, and the hub. Fiber-optic cable shall be used for cables between the hub and the IPCs. All networked devices shall be configured in a star topology with each device connected to a single network hub. Individual devices shall be provided with appropriate network interface cards to communicate with the hub via the particular media type. Failure of any component of the system, except failure of the cable itself or hub, shall not cause more

than one major device (computer, PLC, printer, or modem) to lose communication with the LAN.

The Contractor's System Integrator shall provide all components necessary for the proper operation of the LAN including, but not limited to, cable, end terminators, transceivers, hubs, and controllers. Selection of the appropriate cable and connectors shall be the responsibility of the Contractor's System Integrator and shall be as recommended by the manufacturer of the LAN equipment.

2.1.4.1 Network Hub. The hub shall be a single Fast Ethernet hub containing at least twelve ports. Each port shall provide 10/100 Mbps auto sensing to automatically detect the speed of attached devices. Each port shall support 10BASE-T or 100BASE-TX transmission over 4 pairs of Category 5 UTP cable. Transceivers, as specified below, shall be used to convert between fiber media and UTP at the hub. Devices designed for 10- and 100-Mbps shall be operable at the same time while connected to the hub. The unit shall be self-configuring. The unit shall be provided with an uninterruptible power system (UPS) designed to protect hubs from the effects of brown-outs or spikes. The UPS manufacturer shall be the same as that of the hub.

2.1.4.2 100BASE-TX Network Interface Card. 100BASE-TX Fast Ethernet network interface cards shall be used in the IPCs **[in the central control station]**. The card shall be compatible with the 32-bit PCI bus interface and shall comply with IEEE 802.3U, the Fast Ethernet industry standard. Cards shall be provided with RJ-45 connectors suitable for use with Category 5 UTP cable.

2.1.4.3 100BASE-FX Network Interface Card. 100BASE-FX Fast Ethernet fiber optic network interface cards shall be used in IPCs that require connection to fiber optic cable. The card shall be compatible with the 32-bit PCI bus interface and comply with IEEE 802.3U, the Fast Ethernet industry standard. Cards shall be provided with SC (push-on) connectors suitable for 62.5/125 micron multimode fiber. As an option 100BASE-TX network interface cards may be provided with 100BASE-TX to 100BASE-FX transceivers for converting from UTP to fiber. This option is subject to approval of the Contracting Officer.

2.1.4.4 PCMCIA Network interface card. A PCMCIA network interface card shall be provided for the notebook computer specified below. The card shall be 32-bit Fast Ethernet for 100 Mbps throughput.

2.1.4.5 Network Transceivers. Fast Ethernet fiber optic transceivers shall comply with the 100BASE-TX IEEE 802.3U standard. Transceivers shall support multimode fiber and have 3 dB attenuation or less. Connections shall be push-on type SC fiber connectors and RJ-45 for Category 5 UTP. Transceivers shall be provided with diagnostic LEDs to indicate the unit is powered, fiber signal detected, and twisted pair signal detected.

2.1.4.6 Dial-up Network Router. The dial-up network router shall support a 10 Mbps Ethernet (10BASE-T, AUI) LAN interface. Unit shall support TCP/IP, IPX routing, PPP, and Multilink PPP (MP) protocols. Unit shall provide user authentication for security management. Firewall technology shall be included as a software option. Unit shall be provided, as a minimum, with AUI and 10BASE-T Ethernet ports, and two analog telephone ports (RJ-11 connectors).

2.1.5 Notebook Portable Computer. The Contractor shall provide a portable computer to be used as an IPC workstation and be fully compatible with the IPC network. The notebook portable shall be provided with any and all converters, connectors, power supplies, battery packs, and cables to allow connection to the IPC network. The minimum requirements for the notebook portable computer shall be as follows:

(1) Intel **[166 MHz Pentium MMX]** Processor

(2) **[2.1]**GB (minimum) Hard Drive

(3) [**64**]MB of RAM, expandable up to [**104**]MB

(4) 3.5 inch, 1.44 MB Floppy Disk

(5) Built-in Pointing Device

(6) Two PCMCIA slots

(7) PCMCIA FAX/MODEM (Baud rate to be determined by the Contracting Officer)

(8) [ ] mm ([ ]-inch) (minimum) XGA active matrix color display

(9) Built-in [**8**] Speed CD-ROM

(10) One PCMCIA Ethernet Network Interface Card (10BASE-T)

(11) One Parallel Port

(12) One Serial Port

(13) Microsoft Windows NT Workstation - Latest Version

(14) Software as specified herein.

2.2 SOFTWARE.

2.2.1 General. The Contractor's System Integrator shall develop all operator interactive software. The Contractor's System Integrator shall be responsible for providing, installing, and configuring all software on the IPCs including, but not limited to, the operating system software, the PLC programming software and network drivers, the graphical user interface software, application software, and other device drivers as required.

All software shall be provided either on high-density 3.5 inch floppy disks or CD-ROM. If software upgrades are released by the manufacturer of any installed software during the course of the contract, the Contractor shall acquire and install the latest upgrade. Original labeled disks containing the latest version of each software package shall be turned over to the Contracting Officer at the completion of the contract.

2.2.2 Operating System Software. The operating system software shall be Microsoft Windows NT. The latest versions of both Windows NT Server and NT Workstation shall be provided. However, the System Integrator shall ensure that all application software is certified for use with the latest version of Windows NT and shall only provide the latest version of Windows NT for which the application software is certified. Each copy of Windows NT Server and NT Workstation shall be provided with appropriate Microsoft site licenses to comply with Microsoft's licensing requirements. The IPC located in [**the central control station**] shall be designated and configured as the server. The remaining IPCs located elsewhere shall be designated and configured as clients to the server. Accounting information and passwords for the server and clients shall be set up in collaboration with the Contracting Officer or an authorized representative. In general, the Contracting Officer shall be consulted on all matters pertaining to set up of the IPCs which could involve later reconfiguration by the Government.

2.2.3 PLC Programming Software. See SECTION 16910. Software drivers shall be provided which allow the IPC network interface cards to communicate to the PLC via the Ethernet LAN. Proprietary network interface cards made by the PLC manufacturer will not be acceptable as an interface between the IPCs and the PLC.

2.2.4 HMI PROGRAMMING SOFTWARE

2.2.4.1 General. The vendor is to provide a highly functional, generally available (that is, non-custom) software system for data acquisition, monitoring and control meeting the specifications herein.

****

Note: Because technology advances very quickly in this field, the designer will be required to research the market and update the following specifications for each project.

****

2.2.4.1.1 Operating System. The operating system shall be Microsoft Windows NT **[v4.0 with Service Pack 5]**. The software shall exhibit strong compliance with Microsoft's Windows DNA standards, such as in its use of dialog boxes and menus. The system must support running as a service under Windows NT, making it independent of the NT user login limitations. The system must be year 2000 complaint.

2.2.4.1.2 Configuration. The software shall be configurable by any user on the system. The system shall provide a mechanism for accepting configuration input either directly from the keyboard, via a mouse, or as appropriate, indirectly through ASCII files that are created by an external text editor or relational database program. Source code modifications, re-assembly or recompilation must not be required for implementing user-level system changes. The entire system should be able to be generated automatically through the use of its scripting language.

2.2.4.1.3 On-line Operation. All configuration *changes shall be capable of being made on-line, while the system is operating*. Data definitions, operator displays, etc. shall be capable of being modified, added or deleted without having to interrupt the data acquisition.

2.2.4.1.4 Hardware Requirements. The system shall be capable of operating on a *minimum* configuration of:

- IBM Pentium-BASED 300MHz Personal or Industrial Computer that runs Windows NT
- RAM Memory size:
    - Server: 256 MB RAM
    - Client: 128 MB RAM
- SVGA and a 100% IBM-compatible, 24-bit graphics card capable of 800x600 resolution and at least 65,535 colors.
- 4.0 GB hard disk
- Parallel printer port
- Serial port
- Mouse or trackball
- CD-ROM

Optionally, the system shall also be capable of supporting:

- Network adapter(s): NETBOIS-compatible or TCP/IP-compatible network interface adapter.
- Additional main memory
- Larger hard disk

- Additional printer ports
- Support of multiple port serial add-on boards
- High speed PLC communication cards.
- Touch-screen monitor

2.2.4.1.5 Documentation. The system shall provide complete user documentation, including examples of how to operate the various modules within the system. The documentation must be in electronic format, HTML based with the ability to search for topics by keyword or search or specific text.

2.2.4.1.6 On-line Help. An on-line "help" facility, based upon Windows standard Hypertext, shall provide useful, *context-sensitive* information on the operation of the package. This help facility shall be capable of being invoked on-line through a point-and-click operation. The "help" facility must also support the ability to perform full text word search, add custom comments, bookmark topics, copy and pasting into another application, printing, and use of system fonts and colors.

2.2.4.1.7 Size. The system software shall be provided with capacity for [150][300][1500][unlimited] tag counts.

2.2.4.2 DATA HANDLING CAPABILITIES

2.2.4.2.1 General. *No programming, compiling or linking shall be required to configure the system.* The database tags must be configurable on-line. That is, new function and database tag assignments can be added while the system is performing data acquisition and control operations. The process database containing the current value of the data, or tag list, shall be memory-resident and of a design that is appropriate for real-time monitoring and control functions. Its design shall be optimized for speed, memory usage, data integrity and system security. Floating-point arithmetic shall be used in all calculations. This database shall be stored as a standard Windows file on the local or network hard disk and, upon starting the system, this database is loaded into the computer's memory. The actual application of monitoring and control functions will be dictated by the definition of the contents of this memory-resident database.

2.2.4.2.2 Data Integrity. The software shall provide pre-emptive multitasking to ensure that common Windows actions do not interfere with I/O communications, processing of data, alarming, and the integrity of the real-time and historical data. These common Windows actions include moving a window with a mouse, opening a file, accessing the hard disk, or printing a graphic display. The software shall be written fully 32-bit so that it runs native in the Windows NT operating system. Emulation using 16-bit software code is not permitted.

2.2.4.2.3 Database Tag Configuration. Various input/output hardware assignments, as well as processing functions, shall be assigned to named tags or "function blocks." Multiple tags can be tied together to perform more complex functions. During the configuration process, the program shall be capable of checking the tag structures for correct linkages, appropriate names, and so on. The scan processing program shall also be capable of detecting and handling configuration errors at run-time. Any errors encountered shall generate messages to the user. The user shall be able to perform tag configuration (adding, modifying, deleting, viewing) in several ways, as follows:

1. Directly from the graphics editor, so that tags can be configured as graphics are developed.
2. Via an interactive spreadsheet-style database builder program that uses a fill-in-the-blank menu methodology. The database builder program shall provide the following editing functions:
   - Cut/Copy/Paste tags
   - Duplicate tags
   - Generate multiple tags from a given pattern

- Sort tags
- Query tags
- Display tags in user-configurable formats

3. Via the importation of a Comma Separated Value (CSV) text file developed in another program as input for tag creation. The database builder program shall also be able to export the current tag listing for modification by the external program.

For methods 2 and 3 above, the development of the database tags shall be completely independent of the creation of graphics displays.

2.2.4.2.4 Database verification. The package must also allow for database configuration verification. This task will allow for verification of configuration errors on a local database or a database on another node. Errors shall be reported in a dialog box and a user must be able to make the corrections from this dialog box.

2.2.4.2.5 Tag Database Editing. The database has to allow for editing from a graphic editor, from within the building of a graphic operator screen, or from within a VBA script. The database editing must be able to be accessed locally or across the network. A node can edit a database on another node while online.

2.2.4.3 Database Tag Types. Functions shall be available in the database to support the following tag types:

2.2.4.3.1 Analog Input. This reads an analog value (position, temperature, speed, pressure, level, etc.) directly from the PLC and automatically scales the raw data to engineering units (seconds, revolutions/minute, pounds/sq. in., degrees, etc.). An Analog Input tag must also support write outs.

2.2.4.3.2 Analog Alarm. This provides enhanced alarming capabilities to the Analog Input, including alarm suspension, remote acknowledgment, delay time, re-alarm time, close a contact based on an alarm condition, etc. An Analog Alarm tag must also support write outs.

2.2.4.3.3 Analog Output. This writes an analog value (setpoint, output, speed reference, etc.) directly to the PLC.

2.2.4.3.4 Boolean Logic. This tag-type takes up to eight (8) inputs, typically logical or digital values, and performs Boolean arithmetic on them. The result can then be passed to or used by other tags or applications within the system. The operators shall include:

- OR
- AND
- EQUAL
- NOT EQUAL
- NOT
- XOR
- NAND
- parentheses

2.2.4.3.5 Calculation. This tag-type takes up to 8 variables or constants and performs an arithmetic calculation on them. The result can then be passed to or used by other tags or applications within the system. The operators shall include:

- Add
- Subtract
- Multiply
- Divide
- Parentheses
- Absolute value
- Square root

- Exponentiation
- Natural log
- Base-10 log
- Relational operations (greater than, less than)
- Change floating point values to integers

2.2.4.3.6 Digital Input. This senses the logical on/off state of a limit switch, relay, pushbutton, etc. directly from the PLC. The value shall be displayed in a user-selected format (0/1, open/close, false/true, etc.) A Digital Input tag must also support write outs.

2.2.4.3.7 Digital Alarm. This provides enhanced alarming capabilities to the Digital Input, including alarm suspension, remote alarm acknowledgment, delay time, re-alarm time, close a contact based on an alarm condition, etc. A Digital Alarm tag must also support write outs.

2.2.4.3.8 Digital Output. This sets a logical on/off state in an output relay directly in the PLC. The value shall be accepted in a user-selected format (0/1, open/close, false/true, etc.) The Digital Output tag must provide ability to specify an initial start position.

2.2.4.3.9 Fanout. This tag passes the value it receives to up to five tags within the same database.

2.2.4.3.10 Program. This function provides the user with a procedural language for sequencing, monitoring, and controlling typical process operations, including:

- If/Then go to another step
- Wait until a process condition occurs
- If time-out go to another step
- Go to another step
- Set a tag to a value or the value of another tag
- Open/Close a digital tag
- Set Auto/Manual status of a tag
- Set On Scan/Off Scan status of a tag
- Add/Subtract a value to/from a tag
- Print a message
- Call other program blocks as subroutines
- Run other program blocks in parallel
- Stop other program blocks
- Pause or delay a number of seconds
- Play a .WAV sound file
- Run an executable program

The current step being processed must be capable of being displayed on the operator's CRT. In addition, a debug mode shall be provided to facilitate program checkout.

2.2.4.3.11 Real-time Trend. This tag shall take as its input an analog or calculated value and save up to eighty (80) values. Averaging of accumulated input values will be provided to extend the amount of time represented by the trend block. The data within the tag can be graphically depicted on operator displays.

2.2.4.3.12 Timer. This tag performs a counting operation. It counts in either the up or down direction, from a pre-set value to a target value. Upon reaching the target or time-out condition, a contact may be closed. This tag also supports conditional next block processing. It shall time up to one year. The timer may be started, stopped, reset or resumed based on a sensed condition or operator command.

2.2.4.3.13 Totalizer. This tag-type maintains a floating point total for values passed to it from other database tags.

2.2.4.3.14 SQL (Structured Query Language) Package. This package shall consist of two database tag-types, the SQL Data and SQL Trigger, which facilitate the transfer of information bi-directionally between the data acquisition system and a relational (or other) database management system, based on event, time or both. It shall utilize Microsoft's 32-bit Open Database Connectivity (ODBC) for connection to the external ODBC-compliant database. The capability to transact among multiple databases and multiple rows within a database is required. Also, "Stored Procedures" shall be able to be invoked in the relational database. In the event that the database server is "down" (not available) at the moment that a query is executed, the system shall provide a built-in capability to back up the SQL commands and data to user-definable primary or secondary hard drives. The system shall automatically detect when the database server comes back online, and, at that time, shall execute all of the transactions that it has backed up. Support of communication to multiple relational databases simultaneously shall also be included as part of the HMI package. The following tags shall be included to perform the queries:

- SQL Data. This tag defines the data which is to be transferred between the data acquisition system and the relational database, and also, the direction of information flow.
- SQL Trigger. This tag defines the conditions (triggers) under which the transfer of data will take place.

2.2.4.4 Tag Attributes. Each tag will have an instrumentation tag name of up to 30 characters. The name shall be alphanumeric. All other application programs will use this tagname as their sole reference to the data element assigned. For tags assigned to actual hardware points, they shall also contain fields for:

- Hardware device name
- Hardware address
- Hardware specific parameters
- Signal conditioning requirements

The software shall have the capability of defining simulation tags that receive their values from the operator's keyboard, other internal calculations, or other programs. Tags shall be processed periodically, with the fastest scan rate being **[fifty (50)]** milliseconds. Scan rates shall be able to be set independently for each appropriate tag. Longer scan rates of up to **[twenty-four (24) hours]** shall also be supported. A mechanism for load-leveling, or phasing, the time-based processing of tags is also required. Alternatively, the user may elect to have tags processed on an exception basis. This choice shall be allowed on a tag-by-tag basis. Also, any input tag may be configured as a "one-shot." This will cause it to fetch the value from the PLC just one time when the system is started or the tag is brought on scan. All tags must have a description field. Each tag associated with a hardware address or capable of causing an alarm condition shall have a means of displaying a descriptive message. The descriptor shall be at least 40 characters in length. The system shall provide built-in signal generators, including sine curves and random numbers that can be used for process simulation purposes. Any output or control block must be able to log a "time stamp" when an operator changes a value.

2.2.4.5 I/O DEVICE COMMUNICATIONS. The system must support fast ethernet communication with the **[existing][specified]** programmable logic controller (See Section 16910 – PROGRAMMABLE LOGIC CONTROLLER). Driver Configuration. The communications driver shall be configurable on-line. If supported by the PLC system, block transfers (the ability to acquire multiple variables in one communications request) must be provided. The block sizes and poll times must be individually adjustable by the user. Supported block transfer times vary depending upon the PLC system provided (See Section 16910 – PROGRAMMABLE LOGIC CONTROLLER), but shall be able to run as fast as the PLC can transfer data. Alternatively, exception-based processing may be optionally selected.

2.2.4.6 Display-only Communications. To facilitate more efficient communications with programmable controllers, the system must be able to provide display-only communications. Communications to read or write tags (Analog and Digital Registers) will only be established when a graphics display containing these tags is open. When the display is closed, communications will cease.

2.2.4.7 Error Detection and Recovery. Wherever possible, the device communications program will perform error checking on messages. These error checks will include lost response (time-out) and data error (checksum, LRC, CRC, etc.). Should communications errors be detected, the software shall automatically indicate that the data (on graphic displays, in historical files, etc.) is no longer valid. The invalid data should be replaced with any user defined characters or have the ability to alter the color, or font to let the operator know the data may be invalid. The system shall *automatically attempt to re-establish communications*, and, if successful, shall then replace the characters with valid data. These capabilities shall be built-in to the software and *shall not require any user programming* or other actions to implement. Failover to a user-configurable back-up port shall be provided as a standard function of the driver.

2.2.4.8 OPC Server Connection. In addition to PLC drivers, the process database must be able to send and receive data with an OLE for Process Control (OPC) server. Any database block should be able to receive or send OPC data by supplying an OPC address. The OPC address should be the following syntax:

ProgID;GroupName;ItemID;AccessPath

ProgID is the name of the OPC server, **GroupName** is the name of the OPC group, and **ItemID** is the name of the OPC item. The **AccessPath** is optional, however must be supported, and will instruct the server how to access the data. The system must also be capable of severing OPC information to any OPC complaint database.

2.2.4.9 Diagnostics. The system will provide a diagnostic program capable of running on-line or off-line that can monitor message rates from the communication program. The diagnostic will display the number of new messages, retries, time-outs, and any occurrences of error. For serial drivers, a built-in datascope shall be provided. This datascope function shall allow the user to observe the messages being sent between the computer and the I/O device.

2.2.4.10 I/O & OPC Server Driver Toolkit. A toolkit must be available which will allow the creation of I/O drivers by end users, system integrators, and others. This toolkit must be able to develop PLC drivers as well as OPC Servers through easy to use development wizards. The Toolkit must be able to auto generate documentation.

2.2.4.11 Stand-alone Operation. In non-networked applications, the software shall be capable of performing all desired functions as specified herein, data acquisition, graphics, trending, reporting, etc. within a single computer. Should the Government elect to network the computers at a later time, all that shall be required is to connect each computer to the local area network, and enable the networking functions within the software. *Neither reconfiguration nor duplication of database tags shall be required to make data available to other nodes* that require access to it.

2.2.4.12 NETWORKING AND DISTRIBUTED OPERATION

2.2.4.12.1 General. The system must have a distributed; client/server system architecture based on OPC and Component Object Technology (COM). This architecture will employ a local area network (LAN) as the method for communicating among stations. Each computer may be assigned one or more tasks. For example, computer "A" may be used simply for graphic display, computer "B" may be connected to the PLC and used for data collection, and computer "C" may be used both for display and data collection. **[For purposes of this contract, network configuration shall be as shown on the drawings]**. Configurations shall be

available that provide complete functionality, others that provide read/write access to the data (but do not perform I/O communications themselves), and still other information nodes that provide read-only access to all data on the network. Data shall be available to all computers and individuals on the network that have been provided access and assigned privileges. Real-time data shall be available directly across the network from the computer that acquired it from the PLC. *Configurations that require each computer to contain copies of database tags it needs to access are not acceptable.* The system shall be configured such that the failure of any one computer will not affect the operation of others on the network. It is recognized that data contained in a failed machine will be unavailable to other machines requesting it. *However, the system shall offer the provision for re-starting or re-configuring other stations to take over.*

2.2.4.12.2 Configuration and Expansion. The system will provide an on-line installation and configuration program for configuring the various computers on the network. This configuration program will allow assigning unique node names to each computer as well as selecting the functions that the machine will perform. The system will allow additional computers to be added to the network while on-line, without disrupting the operations of the other machines.

2.2.4.12.3 Local Area Network (LAN) Architecture. The system shall be capable of supporting the following network configurations:

Network Adapters:
- Ethernet

Network Protocols:
- NetBIOS
- TCP/IP

The system must also be capable of running simultaneously with other LAN users who are not operating the data acquisition system software (but who might be using a LAN manager or file transfer software).

2.2.4.12.4 Error Detection, Recovery, and Diagnostics. The system must provide on-line diagnostics that display the current status and operation of the local area network and its nodes. The diagnostic display must include the LAN adapter status for the machine showing the display, as well as the current number of messages, errors and retries. An additional display will show the current session status (established, pending, off-line) of all stations on the network. A session monitor program that automatically monitors and recovers communications must be supplied with the system. *Should network communications errors be detected, the software shall automatically indicate that the data (on graphic displays, in historical files, etc.) is no longer valid* and shall replace the invalid data with any user defined characters or the ability to alter the color or font of the text. The system shall automatically attempt to re-establish communications, and, if successful, shall then replace these characters with valid data. This capability shall be built-in to the software and *shall not require any user programming* or other user-dependent actions to implement.

2.2.4.12.5 Data Handling Without Duplication Of Data. *Tags shall not be duplicated among stations in order to provide access.* Each data value shall be available to all authorized computers and users on the network. However, the data value shall reside only in the computer that is physically connected to the PLC. *Broadcasts of database tags for duplication among machines are not acceptable.* Application programs, such as graphic displays, that need data in another station, must request that data in real-time over the LAN rather than access a copy in their local database. Database tags shall be stored in files for each computer physically connected to process equipment. They shall be loaded into main memory during the startup sequence for that machine.

2.2.4.12.6 Remote Access. The system shall have the capability of creating and modifying tags in one node by operating the graphics editor or database builder program in another node. This operation shall be performed on-line, while the

destination node is operating. This new or modified tag data shall immediately be available to all other nodes on the network. The security system shall restrict access to the database to authorized users. **[Similarly, configuration shall also be available via a computer connected remotely via modems. When a remote computer is connected via a modem, the user shall have the same access as though they were at a computer directly attached to the network. The following functions shall be supported:**

- **Configuring the database tags throughout the network**
- **Viewing graphic displays being updated with real-time data**
- **Viewing historical trend data**
- **Copying files from/to the network]**

[The software package proposed for use on this system must be able to offer the following two fully integrated Internet solutions for future considerations:

- **View across the Internet. A thin client solution that provides authorized users with read-only access to graphics screens using any standard Internet browser.**
- **Push Technology Solution. A thin client product that uses push technology to automatically deliver reports over the Internet using Microsoft's Internet Explorer version [4.0].]**

2.2.4.12.7 OLE OPC and Active X Support. The system must support third-party objects and controls to be plugged in via OLE, OPC and Active X support.

2.2.4.12.8 Dynamic Data Exchange (DDE). DDE support shall be available for data exchange to any third party device that requires this communication. DDE should only be used when no other communication means is available.

2.2.4.13 GRAPHICS CAPABILITIES

2.2.4.13.1 General. The graphics package must provide a means of creating and displaying color object-oriented graphic displays that will be used by the operator to monitor and control the process. Real-time values being read from the PLC shall be capable of being displayed in a variety of user-configurable formats. Graphic displays shall be standard Microsoft Windows files and shall be able to be stored on the system disk, a floppy diskette, virtual (RAM) disk or file server, based on user-entered selections. There shall be no limit (other than physical disk size) to the number of displays that can be developed and accessed on-line. The development and runtime graphics packages must both be multi-document architecture applications. Support for displays larger than the size of the monitor shall be provided. If used, scroll bars shall be provided to allow the user to move to other areas of the display. The graphic screens need to be based on objects and not individual pixels. The object graphics will consist of an image and image attributes, such as size, color, and position that will define the properties of the object. The user will use tools; menus and dialog boxes to change object properties. An object is defined as anything that can be created with drawing tools from within the package or an image imported into the package. All properties, events, and methods of the object must be exposed to the system.

2.2.4.13.2 Graphic Creation. The system shall provide an interactive object-oriented editor or workspace that allows creation of graphic displays using a pointing device (for example, a mouse). A facility shall be provided that quickly toggles, via a mouse click or hot-key, between the graphic building and graphic runtime modes to speed display animation verification and testing during the development process. The software must be designed with the ability to make changes to the graphics while the system is running. Shutting down the system shall not be required to make changes.

2.2.4.13.3 Browser. Once an object is created, the object shall automatically be placed on a tree similar to the browser in Microsoft's Internet Explorer for easy access during all phases of software development.

2.2.4.13.4 Properties Window. A properties window, exposing all properties for an object must live on the workspace. The properties window must support edit functions for any object selected. The properties window shall be accessible from a standard right-click mouse function.

2.2.4.13.5 Object Duplication. Object properties must be passed when an object is copied. Copying should be able to occur from the tree browser or workspace. All properties must be passed on to the duplicated object and the name properties must automatically get changed. Example: When an object with the following properties Name: OVAL; Foreground Color: RED 024 gets duplicated the new objects properties are Name: **[OVAL1][OVALa]**; Foreground Color: RED 024.

2.2.4.13.6 Tile & Cascade. Graphic screens that are opened in configuration mode must support tiling and cascading. Tiling must have horizontal and vertical support and no overlapping when the graphic screens are viewed in this manor. The only limit on the number of graphic screens opened at one time is by the amount of RAM in the PC. Cascading is defined as a method to stagger pictures so they can be selected from their title bar.

2.2.4.13.7 Graphic Sizing. Size will be based on logical units. Graphic screen design at one resolution must be able to run at a different resolution. A full screen option as well as the ability to add sizing borders to any graphic screen must be supported. Also graphic screens must have an option to enable the screen to always be on top and a title bar enabled/disabled option.

2.2.4.13.8 Active X Support. The graphic screens must be an active X document and have the ability to have third party active X OCX, controls dropped in. The system must be capable of containing any control that is placed onto a graphic screen. If a third party control crashes the system must be able to shut down the control while the graphic screen, system, and PC remain running.

2.2.4.13.9 Color Support. The graphics package shall provide support for an unlimited choice of colors with 256 colors supported at any one time. The user shall have the ability to create, save, and restore custom color palettes. Each color must have an associated number so users can selected the color by number.

2.2.4.13.10 Color Palettes. The system must come with a standard, rainbow color palette as well as several standard, shades of color palettes. Each shade palette needs to have 256 shades. The following standard shade palettes must be supplied.

- Cyan
- Gray
- Green
- Magenta
- Red
- Yellow
- Blue

2.2.4.13.11 Color Changes. Color changes must be selectable from editing the individual foreground, background, or edge color property for each object (Accessible with a standard mouse right-click). In addition color changes must be selected from a "Modeless" color box. The "modeless" color box must float on the workspace and allow the user to change color on as many objects as they wish and choose which property of an object or objects they wish to change.

2.2.4.13.12 Global Colors. The system must allow for a global or universal color table selections. This table is based on exact match, or range compression or a value. The colors in the tables will appear on any graphic screen when the value for the data source of the object matches the table. Changes to color tables must

be independent of the graphic screens and not require the user to compile or pass the graphic screen through the graphic configuration program or mode for changes to take place. Changes to global color tables must be supported in the runtime mode.

2.2.4.13.13 Graphic Toolbox. The system must provide configurable toolboxes that the graphics developer can customize as to what tools it contains and their position in the toolboxes. The Toolboxes must be a Window where its shape, size and location can easily be changed with the mouse. Toolboxes shall contain a method, like the ToolTips within Microsoft Word, to describe the function of each tool when the mouse cursor is positioned on a particular tool. Once configured, the state of the toolboxes shall be automatically saved when the drawing session is completed. It shall be returned to that same condition when the next drawing session is started. Users shall have the ability to define their own buttons.

2.2.4.13.14 Graphic Objects. At a minimum, the following object drawing tools must be supported:

- Rectangle/Square
- Rounded Rectangle/Rounded Square
- Oval/Circle
- Straight Line
- Polylines (two or more connected line segments)
- Polygons
- Arcs (curved line segments)
- Chords (a curved line connecting a line segment)
- Pie Shapes (wedges of a circle)
- Text

2.2.4.13.15 Graphic Development Operations. Operations that may be performed on objects or groups of objects must include the following:

- Select/Select All
- Deselect/Deselect All
- Change Color
- Move
- Nudge (move a single pixel at a time)
- Cut
- Copy
- Paste
- Clear
- Duplicate
- Group/Ungroup (objects within a group must be selectable without ungrouping)
- Align (left, right, top, bottom, vertical center, horizontal center)
- Space Vertically/Space Horizontally
- Grid
- Snap-to-Grid
- Reshape
- Zoom In/Zoom Out (50%, 100%, 150%, 200 %, selectable)
- Send to Back/Bring to Front
- Choice of line and fill styles
- Reshape (add/delete/move points)
- Flip horizontally/Flip vertically (mirror image)
- Search and Replace tagnames (including the use of wildcards)
- Undo (the number of levels shall be user-configurable up to 30)
- Cursor position (optionally on the display for exact object placement)
- Rotation (center of motion selectable from any part of the screen)
- Space objects evenly (vertical & horizontal)
- Make objects same size (height, width and both)
- Layers (for building and viewing, up to 20 layers supported)

2.2.4.13.16 Graphic Animation. Each display must have the ability to dynamically update elements in the picture. Defining the method for dynamic update shall be determined by a point and click operation. A pre-defined list of dynamic link elements that shall include the following:

• Data Link	Displays alphanumeric values (numeric values may be displayed in whole number/decimal or scientific notation)
• Time Link	Displays current time
• Date Link	Displays current date
• System Info Link	Displays diagnostic information
• Alarm Summary Link	Displays current alarm information
• Pushbutton Link	Executes a Command Language script
• OLE objects	Displays a third part OLE object

2.2.4.13.17 Dynamic Properties for Objects. Dynamic properties that may be assigned to an object or group of objects must include the following:

Color changes:

- Foreground Color
- Edge Color
- Background Color

Fill Percentage:

- Horizontal (Left/Right)
- Vertical (Up/Down)
- Position/ animation:
- Horizontal (X)
- Vertical (Y)
- Rotate
- Scale

Script Language:

- Commands on down (mouse button or key)
- Commands on up (mouse button or key)
- Commands on mouse click
- Commands on mouse double click
- Commands on mouse move
- Commands on edit

Fill Style:

- Solid
- Hollow
- Horizontal
- Vertical
- Downward Diagonal
- Upper Diagonal
- Cross Hatch
- Diagonal Cross Hatch

Edge Style:

- Solid
- Hollow
- Dash
- Dot
- Dash Dot
- Dash Dot Dot
- Null
- Inside Frame

Objects may be assigned more than one dynamic property. In addition, objects within groups may have individual dynamic properties in addition to those dynamic properties assigned to the overall group. For properties other than "Commands," configuration shall be by "point and click" operations; scripting or programming shall not be required. When building object dynamics properties must support configuration from a dialog box, pop-up menu and user customizable dialog boxes or forms. Positioning property changes must support a method to get screen coordinates and automatically fill in the required coordinates for positioning. The user customizable dialog boxes or forms must be customizable through a Visual Basic Applications (VBA) editor. The system must supply the following pre-built forms:

- Fill
- Rotate
- Position
- Scale
- Visibility
- Edge Color
- Foreground Color
- Background Color
- Data Entry
- Open Picture
- Close Picture
- Replace Picture
- Open Digital Tag
- Close Digital Tag
- Toggle Digital Tag
- Toggle Digital Tag
- Acknowledge Alarm

2.2.4.13.18 Graphic Refresh Rate. The refresh rate shall be user-definable on a per object basis with the fastest rate being fifty (50) milliseconds. It is recognized that achieving this performance is dependent upon the overall system configuration.

2.2.4.13.19 Sources of Data for Object Animation. The animation of the graphics and objects with dynamic properties shall be able to be linked to any of these types of data:

- Data acquired by the system and stored in its memory resident database
- Data acquired by another networked system and stored in its memory resident database
- OPC Data Source
- Variables declared in the command language scripts
- Local and networked relational databases using SQL/ODBC

The system shall provide a wild card supported filter for assigning a data source. The system must provide an expression builder that is accessible from the graphic workspace. The builder will allow an expression to be assigned to the data source. Supported functions of the builder are:

- Addition +
- Subtraction -
- Multiplication *
- Division /
- Left & Right Parenthesis ()
- Equal To =
- Not Equal To <>
- Greater Than >
- Less Than >
- Greater Than or Equal To >=
- Less Than or Equal To <=

2.2.4.13.20 Reusing Graphic Objects. A method shall be provided for allowing graphics objects or groups of objects to be re-used easily. It shall allow the developer to insert native language prompts that request appropriate tag or other animation information whenever the object or grouped object is reused in another graphic display. These objects, either single or grouped, shall be intelligent, Windows wizard-like objects, so that it is possible, for example, to have a single prompt request and substitute:

- A single tag name into multiple dynamic properties within the object
- Multiple attributes (current value, high alarm limit, tag name, etc.) from a single tag into multiple dynamic properties within the object
- Text into the object
- Parameters within command language sequences

A library of these objects shall be included with the standard product. At a minimum, this library shall include:

- Pipes
- Valves
- Pumps
- Motors
- Tanks

2.2.4.13.21 Bitmaps. The system must allow for bitmaps created by other packages to be imported into the graphics, Bitmaps must support a transparent mode and Metafiles must import as objects not just bitmaps. At a minimum the system must support .bmp, .msp, .jpg, wmf, pcx, ico, cur, psd, epr, and wpg.

2.2.4.13.22 Graphic Screen Aliasing. The system must support a means of a generic node name for sharing graphic screen between different nodes with different names.

2.2.4.13.23 Support of Microsoft Excel and Word Documents. Microsoft Excel and Word documents must be able to live within a graphic screen. The documents will run within the graphic, not as an external call. The Microsoft Excel or Word toolbars will get inserted as part of the graphic toolbars for editing.

2.2.4.13.24 Documenting Graphic Displays. Printing of graphic displays in color and black and white shall be supported via the standard Microsoft Windows NT Print Manager in both the graphics development and runtime environments.

2.2.4.13.25 Operator Entry Methods. There shall be provided a flexible, Microsoft Windows NT standard methodology of operator interaction with the system. Input Devices supported by the system shall include:

- Mouse or Trackball
- Touch-screen
- Keyboard (standard or function-style)

The support for and use of any of these entry devices shall be as provided within Microsoft Windows or by the manufacturer of the input device. As appropriate, simultaneous support for multiple of these devices shall be provided.

2.2.4.13.26 Item Selection and Data Entry. Items on a display shall be available to have their values changed by the operator, as appropriate. Selecting an item for data entry shall be done with the use of a pointing device or keyboard. The selected item will be highlighted by a box surrounding it. The system must support the following data entry methods:

- Numeric Data Entry
- Slider
- Pushbutton

- Ramp Value Entry
- Alphanumeric

Each data entry type must be configurable to require confirmation if so desired. The use of third party Active X controls may be used. Refer to paragraph 2.2.4.12.7.

2.2.4.13.27 Operator Action Tracking. The system shall print a descriptive message with a time stamp and user ID on the alarm printer or to an alarm file (if so configured) whenever any of the following events occur:

- Alarm acknowledgment
- Data entry into a tag
- Reloading a database file
- Saving a database file
- Restarting the system

2.2.4.14 COMMAND/SCRIPTING LANGUAGE

2.2.4.14.1 General. The scripting language used by the system must be Microsoft's Visual Basic for Applications (VBA) not Visual Basic or Visual Basic "like." Scripts can be simple or complex and allow users to automate operator tasks, and create automations solutions. The scripting language must use Microsoft's IntelliSense feature, exposing all methods and properties of graphic objects. Editing will be with the Visual Basic Editor (VBE), which is part of VBA.

2.2.4.14.2 Scripting language requirements:

- Animation of objects in pictures.
- Automatic generation of pictures or objects.
- Read from, write to, and create database blocks.
- Automatically run other applications.
- Incorporate custom security features.
- Create custom prompts and messages for operators.
- Access ODBC data sources.
- Incorporate and communicate with third party and custom Active X controls.
- Trap bad or misbehaving Active X controls to prevent crashes.
- Write custom wizards for frequently performed tasks.
- Allow use of global scripts and global variables.
- Scripts become part of the graphic screen.
- The VBE must allow import and export capability.
- The must be a link from the graphic editor to the VBE.
- VBA or the VBE is launched from within the system, without any commands.
- All Properties, methods, and event of Graphic object created within the graphic editor or Third party Active X controls used in the graphic screen must be exposed to VBA.

2.2.4.14.3 Object Hierarchy Overview. The software package shall provide the following VBA overview levels:

- Global level objects. These objects are available to all other objects and contain application-wide information.
- Document level objects. Objects that can contain other objects. Example a graphic screen object containing a shape object, and a toolbar object containing a button object.
- Shapes and user objects. Visible objects, such as shapes, bitmaps, charts, and Active X objects, which can be drawn or inserted in pictures.
- Hidden Objects. Objects that have no graphic representations in graphic screens, however, are available and work with any other object, and perform specific functions. Example would be a timer object.

2.2.4.14.4 Renaming, Duplicating and Moving Objects. If an object is renamed in a graphic screen the name must be changed automatically in the VBA script of form. When an object is duplicated in a graphic picture the script, form and module must also be duplicated and a new name reference must automatically happen for the new object, form, module, and script. When an object is moved between pictures the form, module and script must move with it. If the object is placed into a graphic screen that already is using the same name, the renaming mentioned above must take place for the object, form, script, and module.

2.2.4.14.5 Global Scripts and Variables. The ability to have scripts and variables available across all graphic screens. These global scripts and variables must get loaded when the system is started.

2.2.4.15 MULTIMEDIA CAPABILITY. Support for standard Windows NT multimedia capabilities, including audio and video, shall be provided.

2.2.4.16 ALARM AND MESSAGE HANDLING

2.2.4.16.1 General. The system shall be capable of detecting alarm conditions based on the states and values of the various sensed variables. The alarm conditions shall be detected even if the variables causing alarms are not currently on the display. Alarms will be used to report potentially harmful process conditions requiring a response, typically when a process value exceeds the pre-defined limits. Messages are to report non-critical information that does not reacquire a response. Alarm limits can be entered by the user at configuration time or from the operator's display during run-time. Alarm limits are expressed in engineering units.

2.2.4.16.2 Alarm Types. Analog input or alarm variables shall have the following alarm types:

- High High
- High
- Low
- Low Low
- Time rate-of-change
- Bad input from I/O
- Alarm Disable
- Off Scan
- Deadband

Digital input variables shall have the following alarm types:

- None
- Change of state
- Open
- Close

3-term (PID) control functions shall have the following alarm types (in addition to the alarm types associated with the analog input or alarm block providing the measurement):

- Deviation from Setpoint

Statistical data tags shall support "out of control" alarming on the following limits:

- X bar, range and standard deviation control limits
- ± 2 Sigma X bar
- ± 3 Sigma X bar
- Range
- Trend of runs
- Length of runs

- Critical runs
- Standard Deviation (SBAR)

2.2.4.16.3 Alarm Priorities and Filters. The system shall support at least 3 alarm priorities for each alarm type: High, Medium and Low. A filtering mechanism shall be provided so that the operator can adjust the system alarm priority. The handling shall be as follows:

If priority level is:	Messages will be sent to destinations for tags with:
Low	High, medium, and low alarm priorities
Medium	High and medium alarm priorities
High	High alarm priorities

Special alarm messages (such as PLC failure) shall be non-maskable and shall always print.

2.2.4.16.4 Alarm Areas. In order to logically divide a process into smaller units, the system shall allow for unlimited, named individual alarm areas to be defined. These alarm areas must be definable on an individual tag level. All alarm areas must be accessible by each tag and the system must support multiple alarm areas per tag. Alarm areas are used to determine which destinations receive each alarm. The method of alarm distribution over a network must be session-based in order to guarantee alarm distribution and reception. Broadcasting of alarms on the network shall not be permitted. Each alarm block must be able to support an area that can associate a graphic screen for the alarm.

2.2.4.16.5 Alarm Destinations. The system shall provide a means for placing an alarm message in one or more of the following locations:

- Alarm summary display
- Alarm printer
- Alarm message file on disk
- Alarm history window (first-in, first-out scrolling window on the display)

The system shall allow either COM1, COM2, LPT1 or LPT2 **[these can be rerouted by Windows NT to point to a network printer]** to be the alarm printer. The use of multiple alarm printers shall be supported to allow routing of alarms from different alarm areas to different printers. Alarm messages shall be independently user-configurable as to what information is provided and its sequence within the message. The following shall be available choices:

- Time of the alarm
- Name of the tag causing the alarm
- Alarm condition code
- Engineering units value when the alarm occurred
- Descriptor text assigned to the tag
- Engineering units of the tag
- Directly to a relational database

Also, the user shall be able to specify the length of the alarm queue for each destination.

2.2.4.16.6 Time Stamping. A time stamp must be included with every alarm or message. This time stamp will indicate the time and date that the alarm or message was generated. Time stamping must be supported from the local computer time, OPC server time, or process hardware's clock.

2.2.4.16.7 Auto Alarm Manager. The system must support a method for alarms to be acknowledged from a central location, via modem. The connections from the remote node to the central node must only be live during an alarm condition.

This connection must use Microsoft's Remote Access Service (RAS). The system must support a primary and a secondary selection for alarms reporting.

2.2.4.16.8 Alarm Notification and Acknowledgment. When a new alarm condition is detected, an alarm message will be generated. If the alarm condition code text for the block is on the current display, then the text will flash until the alarm is acknowledged. Alarm acknowledgment will be performed from the operator's keyboard or with the mouse and shall require no more than one keystroke or mouse click. The system must be capable of "freezing" the highest alarm status value on the display until acknowledgment is made. Once acknowledgment is made, the system will display the current alarm status text. The software shall provide built-in capabilities to support the following:

- Remote acknowledgment. This shall allow, for example, a button to be depressed by the operator which closes a digital tag and acknowledges one or more alarm conditions, as configured by the user.
- Alarm suspension. This shall allow the user to specify digital tags, that when closed, cause alarms not to be generated for one or more alarm conditions. This is useful, for example, during the start-up phase of a project to avoid nuisance alarms.
- Re-alarm time. This shall allow the system to re-generate an alarm after a user-configurable amount of time, should the alarm condition still exist.
- Delay time. This shall allow the user to specify a period of time for which an alarm condition must remain before an alarm is generated. This is useful, for example, if certain actions may cause a temporary, but acceptable, fluctuation beyond alarm limits and the generation of alarms is not desired.
- Close contact on alarm. This shall allow the user to specify digital tags that become closed when certain alarm conditions occur. These contacts can then be used to take actions, such as sounding a horn or initiating a sequence of instructions. Also, the user can specify the conditions under which these digital tags are re-opened, including the following:

    - When the alarm is acknowledged
    - When the alarm is cleared
    - When the alarm is acknowledged and cleared
    - Never (it must be re-opened by a different function)

For analog values, re-alarm time, delay time, and close contact on alarm capabilities shall be supported, not just on a tag by tag basis, but for the following individual alarm types within a tag:

- High High
- High
- Low
- Low Low
- Rate of change
- Deviation from target value
- All other

When an alarm is acknowledged from any node on the network, the acknowledgment shall be made directly at the node from which the alarm was generated, and a message indicating that it has been acknowledged shall then be distributed to all alarm destinations. Messages shall be able to be designated as "events-only." These will be distributed to alarm destinations, but shall not require acknowledgment.

2.2.4.16.9 Alarm Summary Display. The system must offer an alarm summary display as a pre-defined, customizable, OCX, dynamic link within the graphics package. This alarm summary display must show a list of the pending alarms in the system. As new alarms are detected, entries are made to the display list. As the alarm conditions clear, the entries are removed from the list. In addition to being able to configure the placement of the information (tag name, current

value, descriptor, time of alarm, and alarm status), the user shall be able to specify the color codes to be used to indicate the various alarm conditions. Alarms can be acknowledged from the alarm summary display either individually (by clicking on an alarm acknowledgment field) or for all alarms in the queue. The alarm summary display must provide sorting and filtering capabilities. The user shall be able to filter on node name, alarm area(s), alarm status and alarm priority. The user must be able to sort on time, tag, alarm area, alarm priority and alarm status. The user must be able to display field or fields about the alarm block in a column format and do complex filtering.

2.2.4.17 ARCHIVING AND REPORTING.

2.2.4.17.1 General. The system must provide a facility for automatically collecting, storing and recalling data. Recalled data will be made available to a trend display program, a report generation program and to user-written programs.

2.2.4.17.2 Data File Handling. Data will be stored in Windows-compatible files in compressed format. Compression will be performed through a user-supplied deadband. Entries containing time, name, value and status will be made in the file whenever the real-time value exceeds the previously-stored value by the deadband limit. A deadband value of zero will cause an entry in the file each time the real-time value is examined. Files shall be organized according to time and will contain values for multiple, named variables. The file can be placed on the hard disk or a floppy disk, and can be placed on a file server if LAN server software in installed. A mechanism for on-line maintenance and automatic purging of files must also be provided. The system must support third party applications for ODBC queries.

2.2.4.17.3 Archive Configuration. The data to be collected by the archiving program will be identified through an interactive, menu-based configurator. The user will enter the tag name, collection rate, and data compression deadband value. Collection Rates are:

- 1 Second
- 2 Seconds
- 10 Seconds
- 20 Seconds
- 30 Seconds
- 1 Minute
- 2 Minutes
- 10 Minutes
- 20 Minutes
- 30 Minutes

The collection task can be run at any one or more computers on the network. The task shall have the ability to access data from the memory-resident tag list in its own computer and/or any computer(s) on the network.

2.2.4.17.4 Displaying Archived Data. The operator shall be able to recall archived data from the disk to be displayed in graphic format along with real-time data. The display of archived data shall be user-configurable. It shall be possible to configure objects in graphic displays that, when selected, fetch pre-defined historical trend data from disk and display it to the operator. The system must allow for users to edit a pen's attributes during runtime. The historical trend display shall be made up of the following components:

- Pen Group. The pen group configuration is used to define the particular tagnames which will be displayed. Along with tagnames, pen color, marker style and engineering units range may be defined.
- Time Group. The time group configuration is used to define the time period over which the archived data is to be displayed.
- Legend Group. The legend group configuration is used to define the legend parameters for a historical display. Both a primary and alternate legend may be displayed.

The display shall support unlimited variables to be displayed on the same time/value axis simultaneously. For each entry in the display list, the operator will be able to assign a given tag name and marker to a particular line color selected from palettes of unlimited colors. The operator may also enter display engineering units ranges to cause scaling of the display. Support shall be provided for multiple, different y-axis engineering units to be displayed, as appropriate. The display shall have two fields of view: The top portion of the screen shall be the graphic field and will display the values of the variables (y-axis) against time (x-axis). It shall also contain labels for the axes and graphs. The bottom portion of the screen shall be user-configurable to display information, such as node names, tag names, and descriptors, pertaining to the tags in the trend display. The trend object will allow for bi-directional trending and scrolling. A user can select right to left or left to right. A movable, vertical line will act as a time cursor on the display. This cursor can be moved by dragging it with the mouse. The date, time, and values of the trends corresponding to that time will be displayed in the bottom portion of the screen. The grid of the trend object shall be scrollable. The trend may be shifted forward or backward in time ("panning") by clicking on left/right buttons. New data will be fetched from the historical file as appropriate. Two sets of buttons shall be provided that cause shifting by different amounts of time. The amount of time shifting caused by these buttons shall be user-configurable. The ability to display historical (pre-collected) data with current (real-time) data on the same chart must be supported. A transparent option for the trend must be selectable. The user shall be able to "zoom" in on any section of the trend display by "cutting" that section with a mouse. The software will automatically re-scale both the y-axis and time axis and will fetch the appropriate data for the time period selected. The trend object must have a refresh rate selectable in .1 second increments from a minimum of .1 seconds to a maximum of 1800 seconds.

2.2.4.17.5 Display Output. The trend graphic display must be printable to a black and white or color printer via the standard Microsoft Windows NT Print Manager. The data contained in the display must also be capable of being sent to an ASCII file or .PRN file.

2.2.4.18 Event scheduling. The system shall support an event scheduler with event-based events, and time-based events.

2.2.4.18.1 Event-Based Events. Event based items are to be used by any data source available to the system to trigger events. The system must be able to trigger an event on the following conditions:

- When the data source resolves to a non-zero value (On True).
- When the data source resolves to a zero value (On False).
- At the specified interval as long as the data source evaluates to a non-zero value (While True).
- At the specified interval as long as the data source evaluates to zero (While False).
- When the data source changes (On Change).

2.2.4.18.2 Time-Based Events. Time-based events are events that occur at a scheduled time and are not tied to a data source. The system must allow for scheduling of the following time-based events:

- One shot. Events that run once at the specified data and time.
- Continuous. Events that run continuously at the specified date and time.
- Daily. Events that run on the scheduled day of the week at a particular time.
- Monthly. Events that run on the scheduled day or the month at a particular time.

2.2.4.18.3 Events with VBA scripts. The system shall support a script-authoring wizard for events. The wizard will generate a VBA script tied to the appropriate event. Once this script is created, editing must be allowed from the wizard or the supplied Visual Basic Editor (VBE).

2.2.4.19 SECURITY MANAGEMENT.

2.2.4.19.1 General. The software shall provide a user-based security system. If enabled, the security system must allow for the creation of users with certain rights and/or privileges. These rights must include the ability to run any combination or all of the applications in the data acquisition system. The ability to allow or disallow users access to change values, such as setpoints and machine-setups, on an individual tag basis shall be supported. Groups of users, such as Operators or Supervisors, can be created and granted rights. All users assigned to a group obtain the rights of the group, although they are still tracked by the system by their individual ID. Individual members of a group may also be assigned additional rights. The security system will support either centralized or distributed security file management. The system must support a tie to Windows NT security. When user-based security is enabled, an audit trail will be generated in the system which will tag every operator action with a user identification (ID). Systems that use a level-based security methodology shall not be acceptable.

2.2.4.19.2 Security Areas. The system must support up to 200 separate security areas. Security areas shall be assignable on a per tag basis. Each tag can be assigned all of the available security areas, none of the available security areas, or up to three individual security areas. Only users with clearance for those security areas shall have the ability to change parameters. Security area names may be up to twenty characters in length.

2.2.4.19.3 Security Manager. The following functions must be supported within the security manager application:

- Enable/Disable user-based security
- Define users, passwords and login names
- Define groups to which users may belong
- Define security path(s)
- Define user and/or group rights/privileges
- Define security area names
- Define system auto-start user

2.2.4.19.4 Securing the Windows NT HMI Environment. The ability to "lock" an operator or other user into the runtime graphics environment shall be provided. Specifically, disabling any combination of the following shall be supported, as configured by the user:

- Starting other applications.
- Switching to other applications that may be running.
- Exiting from the system.
- Restarting the computer using <Ctrl><Alt><Delete>.
- Opening unauthorized graphic screens.
- Closing the current graphic screens.
- Using the system menu.
- Switching to the configuration environment.
- Accessing the system tree.

2.2.4.19.5 Limiting Login Time. The system shall allow for a login timeout setting for each user account. This variable setting will logout an operator when the time interval expires.

2.2.4.19.6 Automatic and Manual Logging In and Out. The system shall support manual login and logout as well as automatic login. In addition security information must be customizable through VBA scripting.

2.2.4.20 REDUNDANCY.

2.2.4.20.1 General. The system must support server backup and LAN redundancy. Both redundancy options are independent of each other. The system may be configured for sever backup redundancy, LAN redundancy or both.

2.2.4.20.2 Server Backup Redundancy. The system shall have a redundancy option that allows a client to connect to a primary and a backup server. Both primary and backup server will be collecting information from the process hardware. When the connection from the client node to the server is lost, the system must allow for the client to automatically switch over to the backup. After a fail-over has occurred the backup node will become that primary node and once the original primary node is fixed or replaced it will be the backup node.

2.2.4.20.3 LAN Redundancy. The system must support two physical network connections between a client node and a server node. Both network paths will be for the same process data and when the connection from one network path is lost the system will automatically fail over to the other path.

2.2.4.21 SOFTWARE TOOLS.

2.2.4.21.1 General. The system must be built on and use industry standard development tools.

2.2.4.21.2 Language. The system must be written predominantly in the C and C++ languages (Microsoft compilers).

2.2.4.21.3 Data Access. The system shall provide an open architecture that allows interaction with other programs. It must provide a mechanism for other programs to access individual data elements and fields (such as the high alarm limit of an analog input) within data elements in real-time. File transfer mechanisms are not acceptable; the access must be direct to the memory-resident database. The following shall be supported:

- ODBC. The system shall support Open Database Connectivity (ODBC) for sharing data from its database to any other ODBC complaint database through SQL queries, via an ODBC dynamic-link library (DLL) driver. At a minimum the database shall support communication to Microsoft Access, SQL Server, and Oracle.
- OLE for Process Control (OPC). The system shall be both an OPC client for communicating to any OPC complaint server as well as an OPC server to serve data to any OPC complaint client.
- Visual Basic for Applications (VBA). The system must have VBA embedded as part of the development environment. VBA support will be used for pre-built scripts and custom scripts. It must also support search and replace and the ability to copy all forms modules and scripts from one object to the next.
- OCX or Active X. The system must support the ability to have any third party OCX (Active X control) placed into its container. All third party controls must have the right to behave like any object created by the system. Also, the system must contain any bad or misbehaving OCX or Active X control and be able to shutdown the control without shutting down the graphic picture, system, or node.
- DDE. The system must support Microsoft standard Dynamic Data Exchange (DDE) Server and Client functionality to share data with other DDE-aware applications.

2.2.5 APPLICATION SOFTWARE. Microsoft Office Professional, latest version, shall be provided with each IPC. Other application software, as deemed necessary by the System Integrator, shall be provided with each IPC. All application software shall be provided with appropriate licenses to ensure compliance with manufacturer software licensing agreements.

PART 3 - EXECUTION

3.1 Installation of Electronic Equipment. All electronic equipment specified under this section shall be protected from such environmental conditions as dust, temperature extremes, and excessive temperature fluctuations while being installed in or on the control consoles. The Contractor shall ensure that such protection is in accordance with the equipment manufacturer's recommendations and with other portions of this specification.

3.2 PROGRAMMING.

3.2.1 Network. The System Integrator shall configure all network software as necessary to provide a completely functional network capable of providing all the control and administrative functions specified herein.

3.2.2 HMI Operating Screens.

****

Note: It is recommended that the designer provide visual guidelines, either in the plans or other separate correspondence, as part of the contract to show the general arrangements of the control graphics to be included with the operating screens. All attributes and dynamics of graphics should be sufficiently described.

****

The System Integrator shall be completely responsible for developing screens [**as shown on the drawings**] to provide a correctly operating system. [**The drawings show the general arrangement the Government intends to use for control purposes. The drawings are not intended to be typical of HMI programming software. This shall be the responsibility of the Contractor's System Integrator.**] All HMI operating screens shall be scalable, including text, for different screen resolutions.

3.3 TRAINING.

3.3.1 General. The Contractor and/or the System Integrator shall conduct on-site training that is specific to the work performed under this contract. Training shall be conducted by personnel employed by the Contractor's System Integrator who are familiar with the system supplied and have experience and training in developing and implementing instruction courses. The Contractor shall not hire personnel solely for the training required under this section.

The Contractor shall submit information on the training program for approval 60 days prior to commencement of the training. This submittal shall include a course outline and course schedule. Training schedule shall be coordinated with the Contracting Officer.

3.3.2 Engineering and Maintenance Training. Training for Government engineering and maintenance personnel shall consist of five 8-hour sessions. A complete overview of the HMI software including all features of the HMI software shall be covered. As part of this training, a test application shall be developed in the presence of the trainees. The test application shall include addressing each type of I/O as used in the project, each type of user interface, Adjustable Frequency Drives, Fiber Optic communications, and any special network features used in the project. Application shall mimic the operation of equipment on the project. The Contractor and/or his System Integrator, has the option of developing or planning development of this application in its entirety ahead of time. However, the entire application shall be developed from scratch, start to finish, in the presence of the trainees. The training shall take place at the System Integrator's shop or other location as approved by the Contracting Officer. This portion of the training may be combined with that as specified in SECTION 16910 – PROGRAMMABLE LOGIC CONTROLLER, or with testing requirements from this and other portions of the specification provided that the requirements of all are met.

3.3.3 Operator Training. The System Integrator shall conduct three four-hour training sessions for operators. This training will be limited to the use of the operating screens to control the equipment.

3.4 TESTING.

3.4.1 Hardware Testing. The IPC hardware shall be tested in two stages. The Contractor and/or the System Integrator, and/or the systems manufacturer, shall submit information on both stages of testing. The first stage hardware test shall demonstrate the operability of at least two of the IPCs (server and client) networked together with all hardware configured for permanent installation. This test may take place either off-site or on-site, but must be performed at least 30 days prior to the scheduled software testing. The second stage hardware test shall be used to demonstrate the operability of the complete IPC system with all IPCs networked together in their permanent configuration. This test must be performed on-site.

3.4.2 Software Testing. In conjunction with the PLC tests described in SECTION 16910, the software test shall test all PLC inputs and outputs from graphical screens developed using the HMI software. A graphical representation of indicating lights shall be used to display PLC inputs. A graphical representation of pushbuttons or selector switches shall be used to toggle PLC outputs on and off. Analog inputs shall be displayed either in a numerical format or through a graphical representation of an indicating meter. As described under the PLC testing, the test shall be used to verify that each PLC input and output is correctly connected and also to demonstrate that the IPC can properly communicate to the PLC. The Contractor's System Integrator may develop the test application using either a tabular format showing more than one input or output on the screen at a time or show each input or output individually with an option to scroll through each one separately. The testing performed by the Contractor and the System Integrator shall verify that all information associated with each I/O point is correct, as built. This includes field device tag number, I/O register number, circuit number, and individual conductor identification. The test shall also demonstrate that the PLC remote I/O network is functioning properly, and all remote nodes are addressed correctly and communicating with the PLC processor(s) and IPCs.

3.5 OPERATIONS, MAINTENANCE, AND INSTALLATION MANUALS. The contractor shall provide complete documentation for the operation, maintenance, and installation of all IPC and network equipment as specified in this section. If possible the information should be provided BOTH in hardbound volumes as well as on CD-ROM.

--End of Section--

CERL Distribution

Chief of Engineers
ATTN: CEHEC-IM-LH (2)
ATTN: HECSA Mailroom (2)
ATTN: CECC-R
ATTN: CECW-EE

Engineer Research and Development Center (Libraries)
ATTN: ERDC, Vicksburg, MS
ATTN: Cold Regions Research, Hanover, NH
ATTN: Topographic Engineering Center, Alexandria, VA

Defense Tech Info Center 22304
ATTN: DTIC-O

10
6/00

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)
09-2000

2. REPORT TYPE
Final

3. DATES COVERED (From - To)

4. TITLE AND SUBTITLE
Critical Evaluation of Lock Automation and Control Equipment at Corps-Operated Navigation Locks

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Patrick Wilson, L.D. Stephenson, and Ashok Kumar

5d. PROJECT NUMBER
CW

5e. TASK NUMBER

5f. WORK UNIT NUMBER
33125

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Construction Engineering Research Laboratory (CERL)
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/CERL TR-00-29

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Headquarters, U.S. Army Corps of Engineers
441 G Street, NW
Washington, DC 20314-1000

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

14. ABSTRACT

A survey of lock automation was conducted at 15 lock sites that use programmable logic controllers (PLC) by visiting the lock sites and interviewing lockmasters, operators, maintenance personnel, and District Engineers in order to evaluate system components. The lock operating components evaluated were divided into the following categories: PLC systems, Operator Interface (OI), sensors and switches, and closed circuit television (CCTV) systems. Where possible, these components were evaluated according to the features available as listed on the manufacturers' specification sheets and by the performances of the components based on the experiences of the lockmasters, maintenance personnel, and operators. Draft specifications for controls were proposed based on these and other evaluations.

15. SUBJECT TERMS
navigation structures; CEGS; locks and dams; programmable logic controllers; automation

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
Unclassified	Unclassified	Unclassified	SAR	294	Ashok Kumar
					19b. TELEPHONE NUMBER (include area code) (217) 352-6511 x7235